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AN ASSESSMENT OF SATELLITE TRACKING TECHNOLOGY IN THE COMMERCIAL TRUCKING INDUSTRY AND ITS POTENTIAL USE WITHIN THE UNITED STATES ARMY'S DISTRIBUTION SYSTEM

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ABSTRACT

Currently, a number of government agencies use various satellite-based tracking and mobile communications systems to maintain visibility of important items that may be "on the move." From the U.S. Department of Energy's tracking of en route shipments of hazardous materials, to various wildlife organizations' tracking of endangered species, the use of satellite-based tracking systems is becoming more and more popular within the government sector as a means of achieving total visibility over its in-transit assets.

In the business world, trucking firms have discovered that large savings, in terms of time, energy and fuel, can be realized using various tracking systems that connect drivers to a central dispatcher who is able to transmit last minute routing changes, traffic updates, and other trip information. Integration of satellite-based tracking and mobile communications systems such as these into the U.S. Army's peacetime and wartime distribution systems to maintain in-transit visibility of critical resources will be key to the Army's maintaining an effective and superior force.

This thesis explores the possible adoption of commercially accepted communications and tracking systems by the defense transportation system, and in particular, the potential benefits that this technology may provide to the U.S. Army.

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Chapter 1

INTRODUCTION

The term 'logistics' takes its origins from the military, where it was very early defined as:

> the branch of military science having to do with procuring, maintaining, and transporting materiel, personnel, and facilities (Ballou, 1992).

While the United States military has always regarded logistics as both strategically and operationally important, the need for an effective and efficient distribution system has never been more apparent than it was during America's involvement in the 1991 Persian Gulf War.[1] Although numerous mistakes were made in the preparation for and the execution of this "100 Hour War," Army logisticians at all levels were nonetheless able to perform their functions adequately through superb human effort, innovation, and improvisation; however, America's involvement in the Gulf War helped to emphasize the fact that technology must be ***further*** integrated into Army logistics in order to provide more effective combat power.[2]

[1] There are three fundamental levels of war: strategic, operational, and tactical. The strategic level is concerned with national objectives, the tactical level is concerned with the execution of battles, and the operational level provides a link between strategic objectives and tactical employment of forces.

[2] From August 1990 to February 1991, America, aided by a United Nations coalition, fought against Iraq in a war known as Desert Shield and Desert Storm.

Given that the current Army logistics system is in need of improvement, the problem to be solved is not dramatically different from the problem facing all military logisticians in time of war, that is, "...to get the right 'stuff' to the right place, at the right time, in the right quantities." The difference today is that failure to do so seriously compromises the Army's ability to rapidly project and sustain its forces over the full spectrum of potential conflicts that it faces. The Army must strive, therefore, to achieve total visibility over its logistics system so that it can determine where its equipment and supplies are at any point in time, and have the flexibility to redirect shipments to the required location.

1.1. Problem Definition

The Army's lack of direct contact with supplies en route to the Gulf War via air and sea lines of communication (LOC) made the prediction of arrival times, stabilizing port operations, and formulating reliable estimates for delivery to customer units extremely difficult.[3] Redirecting supplies to customers while "on the move" *during* the Gulf War was also a problem because transporters were often unable to communicate with their home stations to learn of changes in supply routes or drop-off points. These

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Although American forces waged a 215 day *logistics war*, the ground campaign itself lasted only 100 hours.

[3] Maintaining uninterrupted lines of communication between the operating military force and the base of operations is essential throughout all phases of an operation. All the routes (land, water, air) along which supplies and military forces move must be considered.

transporters were further unable to communicate directly with customers to announce a change in the expected time of arrival (ETA) or a delay in delivery.

If the Army is to maintain a distribution system with visibility over the total logistics system, then high-volume, assured communications are imperative, and the ability to accomplish communications "on the move" is essential. It is equally important that the Army continue to promote standardization and interoperability of its equipment not only with the other military services, but also with the commercial sector. Therefore, incorporation of successful communication technologies from the commercial transportation industry is needed to increase the effectiveness of the Army's wartime and peacetime distribution systems in order to provide in-transit visibility of critical resources, and thereby maintain a superior force. The essence of this thesis thus examines the question:

> How can the U.S. Army exploit the full potential of asset tracking systems to improve readiness and reduce costs?

The intent of this research is to gain a better understanding of the asset tracking systems currently available in the commercial sector, and to assess the value of the information provided by this technology, as perceived by participants in the transportation process. The benefits that this technology may provide to the U.S. Army will be explored.

1.2. Background

1.2.1 Need for Technical Innovation

To be effective, the United States Army must operate efficiently in peacetime, yet be able to expand its peacetime transportation and logistics capabilities to meet a variety of possible crisis levels. Not surprisingly, the military relies extensively on commercial transportation systems in times of both peace and crisis. During the buildup prior to the Gulf War, for example, the trucking industry played a major role in moving the goods and people needed for victory. As reported in briefings given by General Norman Schwartzkopf, trucks, mostly from the commercial sector, were the backbone of the effort (Donohue, 1991).

In order to integrate the commercial transportation systems and the defense transportation system (DTS), the Army must be able to command-and-control both its military and commercial assets in a unified manner.[4] This requires continuously updated information on the status and capacity of military and commercial transportation assets. Because the Army must coordinate many suppliers and transport services and often has no fixed addresses or even known recipients for its deliveries, assured communications between the supplier, transport service, and customers is essential.

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[4] Army transportation operates as a partner in the defense transportation system to deploy, sustain, and redeploy forces on all military operations. Army transportation incorporates military, commercial, and supporting nation capabilities.

1.2.2 Current State

Since the fall of the Berlin Wall in November of 1989, America's role in the world has changed significantly. While its military force structure continues to shrink, its global involvement continues to expand. Over the last seven years, for instance, the number of potential worldwide crises points has doubled to nearly 70. The continued support of peacekeeping activities, humanitarian missions, ongoing contingencies and Joint Chiefs of Staff exercises have seriously strained America's military transportation resources (Rutherford, 1995).

Within the Army transportation arena, there is no existing system that provides movement tracking capabilities. That is, current Army transportation systems lack in-transit visibility.[5] Once a transportation asset leaves the loading area, there is no efficient means to communicate with the operator, and movement control elements must rely on "check points" to inform vehicle operators of any route or destination changes, or to warn them of identified enemy locations.[6]

The solution to the Army's transportation inadequacies may lie within the commercial sector, where numerous technologies capable of fulfilling the Army's needs

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[5] In-transit visibility is defined by the military as the ability to identify and track the movement of defense cargo and personnel from origin to destination during peace and war.

[6] Movement control organizations exist at each level of war: strategic, operational and tactical. Their mission is to manage the flow of units and sustainment materiel into, through, and out of a combat theater.

are currently in use. Because the Army depends so heavily on the commercial transportation industry to help move its forces and materiel during crises, it must work to adopt the most effective commercial technologies. In this way, the Department of Defense (DoD) not only saves research and development (R&D) funds, but also ensures compatibility with its civilian counterparts.

In the commercial trucking industry there are several varieties of mobile communications systems currently in use which help in the tracking of cargo, including advanced satellite services, which provide complete geographic coverage anywhere in the world; cellular based systems, which provide seamless communication for both voice and data on a national network; meteor-burst technology, which utilizes high-frequency radio waves; and simple paging systems, which alert a driver by light, beeper, or both. Some of these systems were used on a relatively small scale in the Gulf War, while others have been tested in the peace keeping missions in Somalia, Haiti and Macedonia. Additionally, satellite-based tracking devices have been installed and are in use by a number of vehicles involved in the current United Nations mission in Bosnia. However, to date, in-transit tracking by the military has been very limited in scope and performed only by a select group or unit. As yet, the Army is still in a testing phase.

If the Army is to maintain an edge in the actual battle space, that is, project the force rapidly and sustain the force throughout the fight, it must constantly pursue "the innovation of technology." In the logistics arena, Total Asset Visibility (TAV), or "knowing what you have and where it is at all times," will be achieved only through the

continuing leveraging of technology.[7] While high tech systems may be the optimal choice, the Army must also consider the use of other, less encompassing technologies to serve as backup systems in case of technology failure. That is, if a certain technology is lost due to hostile attack or simply due to system failure, a *redundant* system must be in place and readily available to ensure mission accomplishment.

1.2.3 Emerging Doctrine and Technology

Army doctrine has changed dramatically over the past fifteen years, reflecting the adaptation of technology to new weapons systems and capabilities, organizations, missions, training, leader development, and soldier support. Furthermore, advances in technology are continually changing the way warfare is conducted (U.S. Army, 1993).

In a February 1995 statement to the Senate Armed Services Committee, Air Force General Robert L. Rutherford, commander of the United States Transportation Command (USTRANSCOM), warns that in light of current Department of Defense downsizing efforts, "We must do all that we can to efficiently utilize our organic transportation resources while simultaneously leveraging commercial industry capabilities." He further points out that the importance of command and control systems for the defense transportation system has radically increased, making communications with our mobile

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[7] Total asset visibility permits supply managers to quickly locate, distribute and redistribute equipment and supplies. Current and certain knowledge of the location of the supply items allows managers to divert materiel to priority units and locations.

assets imperative. Ensuring that the right supplies arrive at the right location at the right time, and enabling commanders to divert shipments while en route are critical capabilities that must be provided. General Rutherford continues, "Our current systems and processes are marginally adequate to support our mission. However, based on our defense transportation system, fielding a state-of-the-art, customer-focused command and control system will likely be the greatest **force multiplier** we have to offer the war-fighting commanders."[8]

USTRANSCOM has embarked on a multitude of programs to make this happen. One of the programs for which USTRANSCOM is responsible is the Global Transportation Network (GTN), a multi-million dollar database system that will collect, integrate, and distribute military logistics data. GTN will provide information on the location of deploying units' personnel and equipment sustainment cargo, and other vital resources while they are in the defense transportation system. Additionally, GTN will be able to tie together transportation data from any of the other military transportation commands, and other DoD agencies (see Figure 1). This integration of information will significantly improve the capability of the combat commander to respond to rapidly changing priorities (Rutherford, 1995).

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[8] Correlations of combat power between opposing forces are often so close that a small advantage gained by one side over the other can prove decisive. A customer-focused command and control system will increase the capabilities of U.S. forces and facilitate the execution of complicated operations.

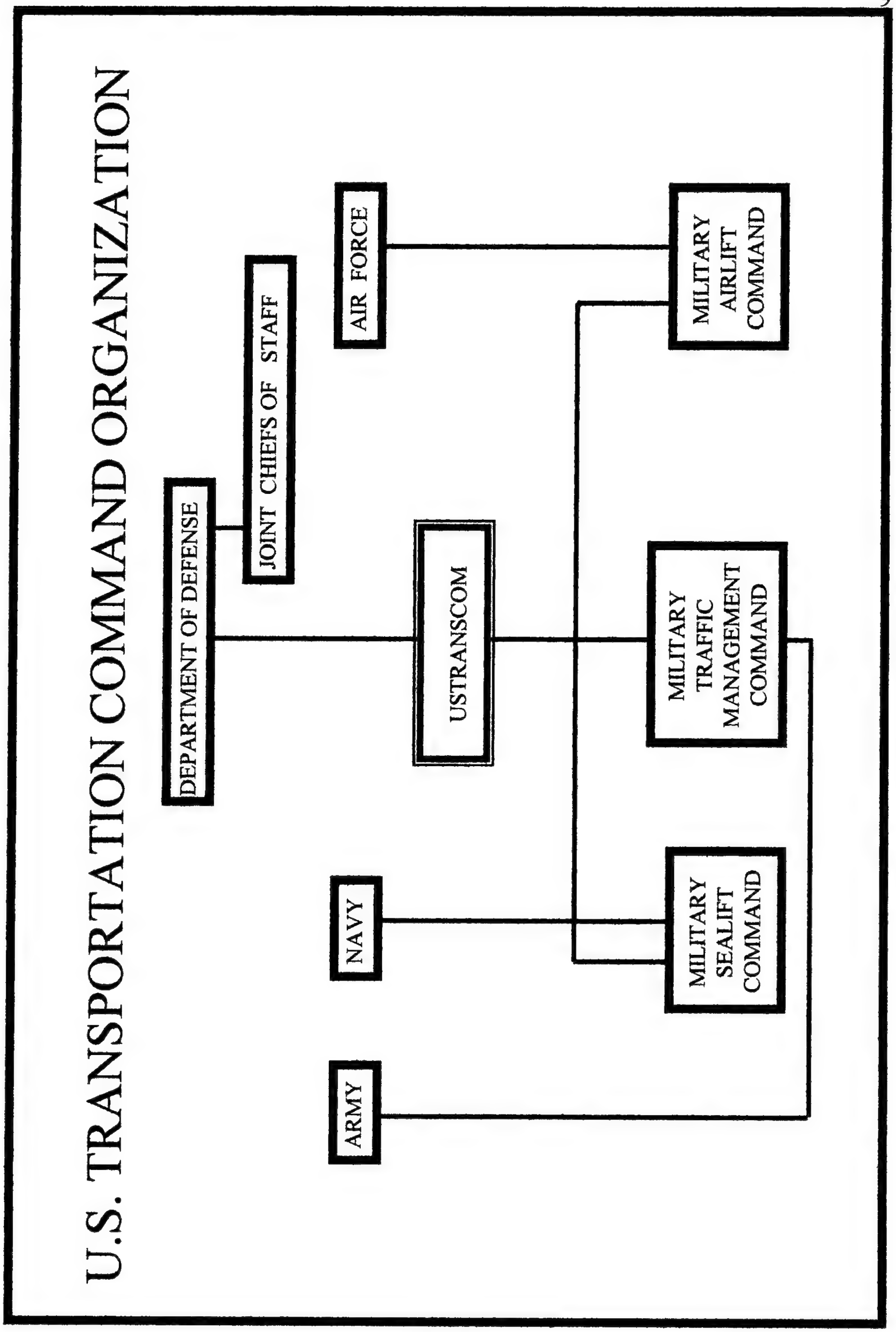
U.S. TRANSPORTATION COMMAND ORGANIZATION
DEPARTMENT OF DEFENSE
JOINT CHIEFS OF STAFF
AIR FORCE
NAVY
ARMY
USTRANSCOM
MILITARY AIRLIFT COMMAND
MILITARY TRAFFIC MANAGEMENT COMMAND
MILITARY SEALIFT COMMAND

Figure 1

There are over 120 transportation information systems currently being explored and/or developed by the joint transportation community (Air Force, Army, and Navy). Some of those being pursued by the Army include: Automated Identification Technologies (AIT), Microcircuit Technology for Logistics Applications (MITLA), and the Movement Tracking System (MTS). Together, these systems will allow commanders to maintain in-transit visibility of supplies from source to user. Furthermore, the MTS will provide the ability to re-route supplies to higher priority needs, avoid hazards, and inform operators of unit location changes.[9]

Lessons learned during the Gulf War confirmed the Army's operational deficiencies associated with movement tracking. Specifically, the inability to track, communicate with, and re-route tactical wheeled vehicles resulted in the inefficient use of limited assets and an increased risk to personnel and equipment. Additionally, there was a problem with getting supplies to the correct customers because drivers often had no way of knowing when units would pack up and move, or when supplies had to be re-routed. As a result, numerous experiments and demonstrations have been conducted since the Gulf War to develop in-transit visibility capabilities and to test new technology.

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[9] The Movement Tracking System is part of a suite of digitization additions planned for tactical wheel vehicles and will play a vital role in future battlefield distribution operations.

One such experiment took place in March 1993, when the U.S. Army Transportation School (USATSCH), in conjunction with the Department of Transportation's Volpe National Transportation Systems Center, participated in a test of the Movement Tracking System. Using satellite technology, a unit's weapons systems, cargo, vehicles and other logistical assets were tracked from Hawaii to the shores of Beaumont, Texas, and eventually on to Fort Chaffee, Arkansas. A Data Fusion Center, located at the Volpe Center in Cambridge, Massachusetts, functioned as a liaison between the sender and the receiver, storing and managing data as it was received.[10]

By using the Movement Tracking System, port operators were able to schedule longshoremen and port clearance transportation with full knowledge of the ship's arrival time. The system also enabled commanders to plan their operations more effectively by providing them the information necessary to divert resources to other units. In the future, information provided by the MTS will allow commanders to make better tactical decisions on the battlefield concerning movement of personnel and equipment. Since the experiment was deemed a success, further development and testing of the Movement Tracking System was, therefore, justified (Galarza, 1994).

A second test of satellite tracking technology took place in the Spring of 1994, wherein USTRANSCOM employed two different tracking systems: the Defense

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[10] The Volpe Center is a research and development arm of the U.S. Department of Transportation (DOT). It works to facilitate unified in-transit visibility capabilities, information systems interfaces, and advanced transportation systems technology concepts.

Transportation Tracking System (DTTS)[11] and the International Maritime Satellite (INMARSAT).[12] For this operation, a shipment of Patriot missiles was continuously monitored from Texas to South Korea. Due to the Defense Transportation Tracking System's limited area of coverage (mainly North America, North Atlantic and Europe), INMARSAT had to be employed for the ocean crossing and again for the inland portion, once the shipment arrived in South Korea. Through the use of satellite beacons, INMARSAT was able to provide updates on the ship's locations every six hours, thus allowing USTRANSCOM to order the ships' speed increased to meet the scheduled delivery date in South Korea (Smith, 1994).

Although the Patriot missile deployment was determined to be a success, one minor problem could have proven disastrous had it occurred in wartime: the shipment departed its point of origin before complete shipment data and documentation had been provided. As was learned in the Gulf War when over 27,000 containers of material had to be opened in Saudi Arabian ports to determine their contents, undocumented cargo can produce chaos. Furthermore, military logisticians concluded from this operation that it is

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[11] The Defense Transportation Tracking System is a computer-based system which provides safety, security and in-transit visibility of sensitive continental United States (CONUS) shipments during their movement from origin to destination. Currently, this system is used only by commercial motor vehicles under contract to transport sensitive shipments for the Department of Defense. There are no plans at this time to share this capability with the defense transportation system.

[12] INMARSAT is a London-based satellite communication cooperative of 55 nations, including the United States, which provides communications to aircraft, ships and land vehicles.

best to have a single satellite tracking system cover a movement, thereby alleviating the need to physically replace satellite tracking devices when systems are changed out (Bonney, 1994).

At the conclusion of the operation, Lieutenant General Kenneth R. Wykle, deputy commander in chief of USTRANSCOM remarked,

> Tracking transportation movements using satellite shows real merit in DoD's ability to monitor assets and provide almost instantaneous shipment location visibility (Bonney, 1994).

1.3. Scope

This research concentrates on the tracking of mobile assets. While there are several types of tracking systems currently available to the commercial trucking industry, this thesis will focus mainly on *satellite-based* tracking technology. Furthermore, while rail, air and water modes of transportation can also benefit from the employment of satellite communication services, this research will focus on the motor freight segment of the U.S. national transportation system.

1.4. Hypotheses and Evaluation Criteria

Four hypotheses form the basis of this research. They are as follows:

$\mathbf{H_{0,1}}$: The time savings resulting from the use of satellite tracking systems will positively impact the decision to purchase this technology.

$H_{0,2}$: The increased productivity resulting from the use of satellite tracking systems will positively impact the decision to purchase this technology.

$H_{0,3}$: Improved customer service resulting from the use of satellite tracking systems will positively impact the decision to purchase this technology.

$H_{0,4}$: Increased return on investment (ROI) resulting from the use of satellite tracking systems will positively impact the decision to purchase this technology.

It is expected that the benefits associated with, or provided by, the incorporation of satellite-based tracking technology to a distribution system will result in a higher level of efficiency and effectiveness, and will thus positively influence a firm's decision to purchase this technology. If we examine the effects that satellite-based tracking technology has on the performance of a commercial transportation organization, we can estimate its usefulness in the Army's distribution system.

1.5. Research Methodology

As stated earlier, the research in this thesis centers around the use of satellite-based tracking systems in the commercial trucking industry, since trucks, more than any other mode of transportation, are used on a regular basis in DoD operations. A review of current literature regarding the use of satellite-based tracking systems within the commercial trucking industry revealed that several benefits were indeed the direct result of satellite technology. What was not covered in the literature, however, was the extent to which users value the technology. That is, while several benefits were stated, very few

were actually quantified or backed with statistical data. Combined, these benefits most definitely proved satellite tracking to be a viable system for monitoring in-transit assets. But separately, it was difficult to determine which benefits were primarily responsible for the increasing popularity of satellite tracking technology.

Four of the most recurring benefits were formulated into hypotheses (see previous section). A 26-item questionnaire was then developed, incorporating specific questions regarding time savings, increased productivity, improved customer service, and increased return on investment. The survey was distributed to all Continental United States (CONUS) members of the American Motor Carrier Association, according to the latest listing, published in the Fall of 1995.

Specifically, the benefits of using satellite-based tracking technology to monitor in-transit assets will be assessed using a survey that will measure the overall satisfaction and value associated with the tracking systems not only in dollar savings, but also in time savings, improved customer service, and increased productivity. In addition, firms that do not, by choice, use satellite tracking will be investigated to determine the basis for their decision against the use of such technology. The results of this survey will then be translated into meaningful military or ***warfighter*** terms in order to project the possible benefits that such technology may bring to Army logistics. For instance, if it is discovered that the greatest benefit of satellite tracking technology in the commercial sector is time savings, inferences can be made regarding "decreased response time" or "reduced closure time of supporting force to supported force," two important aspects of

battlefield supply operations. If increased productivity is found to be a benefit of satellite tracking technology in the commercial sector, corresponding military benefits may include "increased readiness," "increased combat effectiveness," "reduced attrition," or "ability to divert on-the-move." The military equivalent of Return on Investment (ROI) may be the measures of "combat capability" and "force effectiveness," and improved customer service could translate to "increased readiness." Depending on the findings of this research, comparable military benefits will be projected and/or determined.

1.5.1 Assumptions

In the commercial transportation industry, satellite tracking of mobile assets is performed using either the government-owned and operated Global Positioning System (GPS) or other commercially launched satellites. Since the GPS was developed specifically for military use, and since its acquisition costs have already been paid, the following assumptions will be made for the purpose of this research:

- Satellite-based tracking systems provide more optimal capabilities than other systems (cellular, meteor-burst, or beeper systems) and are therefore the Army's preferred technology.

- The Global Positioning System, as opposed to other commercially owned and operated satellite systems, will be the preferred satellite system to be used in conjunction with any mobile tracking hardware or software adopted and/or

purchased by the U.S. Army.

- The U.S. government will eventually begin to charge commercial users of the Global Positioning System in order to recover operation and support costs of the satellite system.

- The Army needs 24-hour, all weather access to navigation and positioning information; therefore, redundant or complimentary tracking systems are necessary for continuous monitoring of valuable assets.

These assumptions are not intended to limit the Army's choice for redundant or complimentary systems. On the contrary, the Army *must* consider the use of commercial satellites and other forms of mobile communications systems as alternative means of satisfying their asset tracking requirements.

1.5.2 Literature Review

An integral component of this research is ensuring a complete review of the most current literature relevant to the problem. The key literature pertaining to this research comes from the areas of:

- military operational and logistics doctrine
- satellite-based communications systems
- transportation and fleet management

The specific concepts in each area that deal directly with this problem include:

- a “seamless” distribution system is necessary
- assured communications are essential
- in-transit visibility is required
- technology must be leveraged

The literature review provides support for the increasing focus of carriers, shippers and logistic professionals on the capability of wireless communications technology to provide transportation support for all phases of the logistic process.

1.6. Summary

The intent of this introduction was to define the problem, provide background information, and discuss the research methodology. As the United States Army moves into the 21st century, it must continue to adopt technologies which will make it more effective and more efficient. This research is intended to propose the idea that incorporating technology can indeed increase simplicity. That is, as we integrate technology into Army logistics, the result does not have to translate to a more complex battlefield.

Chapter 2

LITERATURE REVIEW

2.1. Introduction

A nation's capability to adequately meet logistics needs has historically been a major limiting factor in military operations. For the United States, at least, the root of the problem both in the past and even now, is the inherent complexity of distribution. During the Gulf War, for example, even though American forces possessed the most sophisticated weaponry in the history of warfare, they failed to apply the same level of expertise when developing their distribution plan. As a result, moving and supplying the fighting force challenged America's strategic transportation system like never before (Menarchik, 1993).

Since the conclusion of the Gulf War, much has been written about the military's need for Total Asset Visibility (TAV) and the importance of "leveraging technology." A review of literature pertaining to lessons learned during the Gulf War and current military movement control practices provides a deeper understanding of the Army's deficiencies regarding asset visibility. Additionally, a review of mobile communications systems, as well as the history behind this technology, provides a foundation for assessing the current commercial systems being used within the commercial trucking industry. Details of the government-owned and operated Global Positioning System are presented to provide a

better understanding of satellite-based tracking systems and to allow for an informed comparison of different hardware and software systems currently available within the commercial trucking industry.

2.2. Logistics Defined

Within the business sector, the tasks typically associated with logistics have always been performed, though not always by a designated person or department. Recently, however, the logistics function has been recognized as an independent variable, and rather than falling under the umbrella of operations, marketing or finance, logistics has been developed into a separate department in many firms. Recognition of the importance of logistics, both on the operational and strategic levels, is growing among senior business executives.

As mentioned at the onset, the term *logistics* takes its origins from the military. Simply defined, logistics is moving military forces and supplying them in the field. However, the private sector business provides its own definitions. For example, the Council of Logistics Management (CLM) defines logistics as follows:

> Logistics is the process of planning, implementing and controlling the efficient, cost-effective flow and storage of raw materials, in-process inventory, finished goods and related information from point of origin to point of consumption for the purpose of conforming to customer requirements.

A second, perhaps more applicable definition for this research states:

> The mission of logistics is to get the right goods or services to the right place, at the right time and in the desired condition, while making the greatest contribution to the firm (Ballou, 1992).

However, since this research centers on military applications of commercial logistic practices, a definition from the great Civil War cavalry officer, Nathan B. Forest, merits mention: "Get there first with the most." (Menarchik, 1992)

Army commanders and their staffs are further provided with the following seven principles of logistics, which are intended to serve as a guide for planning and conducting logistic support:

responsiveness: perhaps the keystone among the logistic principles, it is the right support in the right place at the right time.

simplicity: a principle that often fosters efficiency in both the planning and execution of logistic operations, it is the avoidance of complexity.

flexibility: the ability to adopt logistic structures and procedures to changing situations, missions, and concepts of operation.

economy: the provision of support at the least cost.

attainability: the ability to provide the minimum essential supplies and services required to begin combat operations.

sustainability: a measure of the ability to maintain logistic support to all users for the duration of the operation.

survivability: the capacity of the organization to prevail in the face of potential destruction.

While each principle is important in and of itself, seldom will all logistic principles exert equal influence. That is, a given situation or mission will usually dictate that one or two will dominate. Moreover, it is important that these principles not be used as a mere checklist, but as a guide for analytical thinking and prudent planning (see Figure 2).

Related to these logistic principles are five characteristics which help to facilitate effective, efficient logistics operations:

anticipation: identifying, accumulating, and maintaining the assets and information necessary to support operations at the right times and places

integration: uniting logistics concepts and operations with strategic, operational, and tactical plans may yield efficiencies not otherwise achievable

continuity: logistics operations cannot be interrupted and must be adaptable to changing missions and priorities

responsiveness: the ability to adapt to new requirements and changing situations, often on short notice

improvisation: the talent to make, invent, arrange, or fabricate what is needed out of what is at hand

These five characteristics enable operational success. They apply to both war and operations other than war (U.S. Army, 1993).

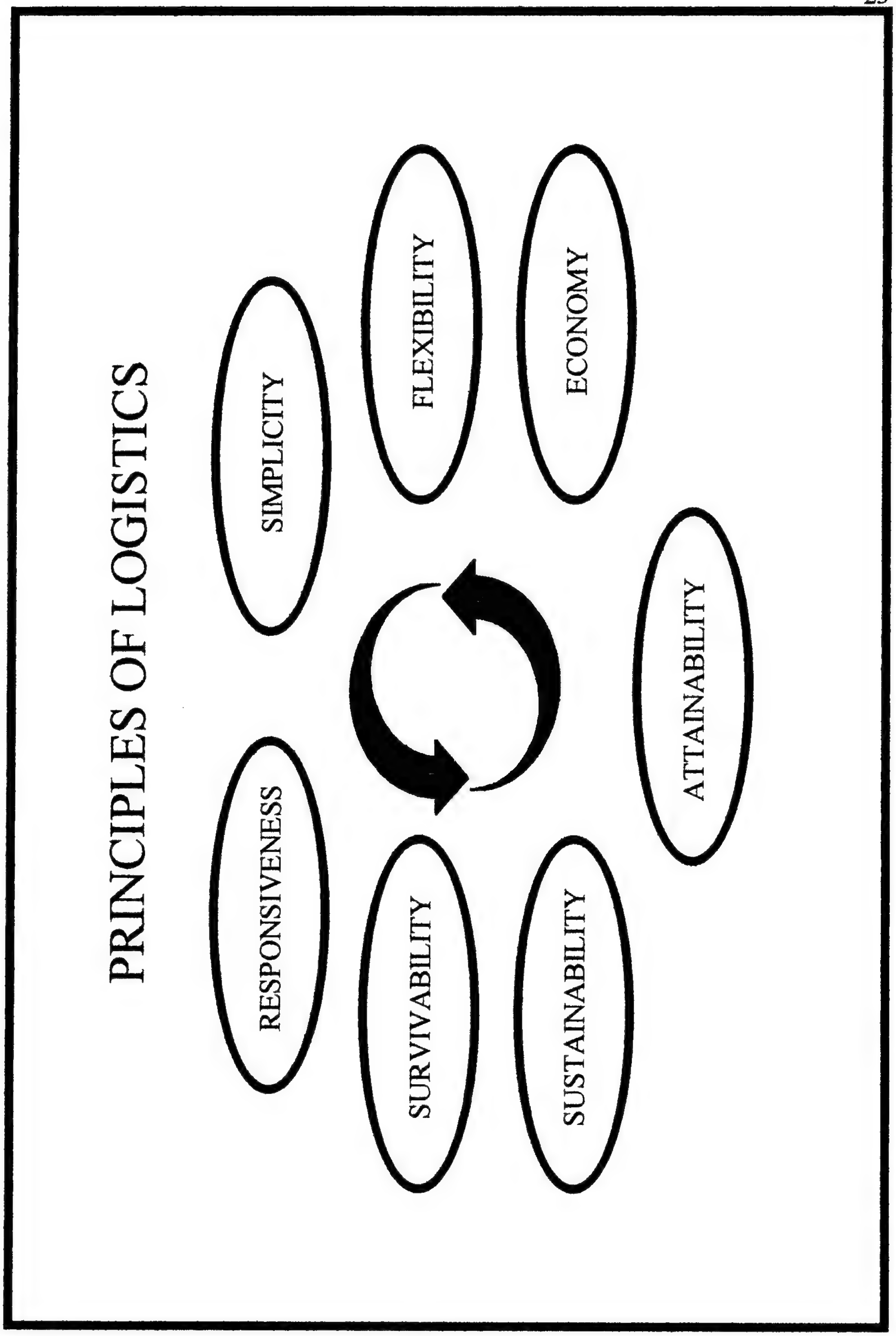
PRINCIPLES OF LOGISTICS
SIMPLICITY
FLEXIBILITY
ECONOMY
RESPONSIVENESS
SURVIVABILITY
SUSTAINABILITY
ATTAINABILITY

Figure 2

2.3. Lessons Learned

Distribution problems surfaced early in the Gulf War as a result of the "push" system used to rush supplies to Kuwait before an adequate logistics structure was established to handle the incoming cargo. Consequently, supplies backed up at the debarkation ports, resulting in bottlenecks. In the future, logistics planners must *anticipate* congestion and identify bottlenecks en route to or within the theater of operations, and further coordinate activities to avoid overloading the lines of communication (U.S. Army, 1993).[13]

In Saudi Arabia, a low ratio of logistic units to combat units was one aspect of the congestion problem; as a result, a number of combat units had to be diverted to perform supply and transport functions. Additionally, U.S. forces were short trucks and services during the conflict to distribute the supplies and take care of the troops, so commercial transportation and services had to be acquired (Pagonis, 1992).

Future regional conflicts will more than likely have the U.S. again borrowing from its friends and allies for strategic and in-theater transportation requirements, especially in light of declining forces and defense budgets. Considering the possibility of the many varied transportation assets that may be involved, it only makes sense that a sound plan for tracking mobile assets be developed and incorporated into Army doctrine now if the U.S. is to maintain its strategic transportation system.

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[13] A theater is a geographical area outside the Continental United States. Part of a theater may be in a state of war, while other areas remain in conflict or peace.

2.4. Emerging Military Operational and Logistics Doctrine

The Army's transportation system consists of several movement control organizations, each of which uses automated systems to plan, program, and allocate resources, synchronize transportation activities, and provide in-transit visibility of movements. At the strategic level where deployment takes place, USTRANSCOM is the senior movement control element (see Figure 1 on page 9).[14] The Military Traffic Management Command (MTMC), which is the Army component of USTRANSCOM, is responsible for the planning and routing of Continental U.S. (CONUS) commercial movements through CONUS water terminals.

At the operational and tactical levels, the critical movement control units are a movement control battalion at echelons above corps, a corps movement control center (MCC), and an assortment of movement control teams, which are organized either by a specific function that they perform, or by an area in which they serve. At each level, movement managers must coordinate routinely with operations planners, materiel managers, military police and other support personnel in order to avoid congestion. Additionally, movement control elements must coordinate with other services and countries when operating as part of a joint or multinational force. This need to coordinate requires access to communication and information systems to determine what to move,

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[14] Deployment refers to the relocation of units and their sustainment equipment and supplies, and involves all activities involving movement from origin to the point of debarkation.

when, where, and how. Thus, source data automation and automated identification technology are essential aspects of control, as is integration with other management information systems (U.S. Army, 1995a).

In addition to communication and information systems, position and navigation devices are needed to track the movement of transportation assets and supplies. When coupled with satellite-based communications, this capability provides real-time command and control to commanders. Commanders are able to tailor and adjust missions and assets in response to the situational awareness gained by having these capabilities available (U.S. Army, 1995b).

2.5. Satellite Communications

2.5.1 History of Mobile Communications and Satellite Tracking Systems

While electronic communications between the U.S. and foreign countries date back to the laying of the first trans-Atlantic cable in 1866, radio communications did not appear until the early 1900s, and focused primarily on the need to communicate with remote mobile units, such as ships, and with less accessible locations, such as islands, where wires were not practical. One of the earliest applications of wireless communication was in the area of emergency assistance, and the sinking of the Titanic in 1912 brought this use to the attention of the population at large. By the late 1920s, two-way radio systems were routinely used in law enforcement, and the use of such systems expanded rapidly during the 1930s. Other sectors adopted mobile communication

technology during the late 1930s and 1940s; rapid growth in industrial and commercial uses began in the mid-1940s. Following World War II, there was a tremendous expansion of the technology due to technological improvements introduced by the military during the war (Robinson, 1978).

It was many years before mobile communications had an impact on the commercial trucking industry. The man considered by many to be the "founding father" of mobile communications in the transportation sector is Dr. Irwin Jacobs, an electrical engineer and businessman. After spending several years in the television industry developing satellite communications between ***fixed*** points, Jacobs decided to pursue wireless ***mobile*** communications. Initially, Jacobs considered defense applications for his developments, but a true businessman, he quickly discovered that the transportation field held more potential for profit. Conquering his first problem, the mounting of a directional antenna on a moving truck (he used a rotating beacon that turns like the light on top of a police car), Jacobs soon gave birth to a new technology: **satellite-based mobile communications**. In 1985 he started his own company, Qualcomm Corporation, to supply truck fleets with satellite tracking hardware (Mele, 1993).

2.5.2 Development of the Global Positioning System

Several years before the innovations of Irwin Jacobs, nations were racing to develop space-assisted methods of communication. Russia was first to launch an earth satellite with its 1957 "Sputnik," but the U.S. followed in 1960 with a grapefruit-sized

satellite called "Vanguard." Soon after, the U.S. launched "Score," "Courier," "Relay," and the more popular "Telstar." However, little coverage was given in the press about using these artificial "moons" to relay communication signals on earth (Williams, 1982).

In 1963, a team was formed with representatives from the Army, Navy, Marine Corps, Air Force, and Defense Mapping Agency to study the concept of using radio signals transmitted from satellites for positioning and navigation purposes. Code named Project 621B, these studies developed concepts and experimental satellite programs, which became the building blocks for the Global Positioning System, or GPS. An all-service navigation system, GPS would provide a highly accurate, secure, reliable way for U.S. forces to navigate anywhere in the world, without having to reveal themselves through radio transmissions (Pace, 1995).

During the developmental stages of GPS, finding money within the Department of Defense to fund the project was a difficult task because GPS is considered a support system, as opposed to a weapons system. To achieve funding, developers proposed that the technology be offered to civilian users. While this idea helped appease many of the project's critics, *official* pronouncement of civilian use only came in 1983, following the downing of Korean Air Flight 007 after it strayed over territory belonging to the Soviet Union. Subsequently, President Ronald Reagan declared that the United States would make GPS available for international civilian use *free of charge* to help prevent future accidents from navigational errors. In the decade since this proclamation, sales of civilian receivers have grown so rapidly that they now exceed the number of military

receivers. Furthermore, the U.S. government predicts that by the year 2005, the number of civilian GPS users will be 84 times greater than the number of military users (Lachow, 1995).

2.5.2.1 How GPS Works

The Global Positioning System consists of three segments: a group of 24 satellites in high-altitude orbits around the earth (three of which are spares); a control segment that includes a control center and access to overseas command stations, all of which monitor the orbits of the satellites; and individual user receivers (see Figure 3).

While GPS receivers do not replace the map and compass or some of the other navigation systems currently available, these lightweight man-portable systems satisfy more of the Army's requirements than other available systems. The data available from these receivers increases the efficiencies and effectiveness with which Army forces maintain asset visibility (U.S. Army, 1995b).

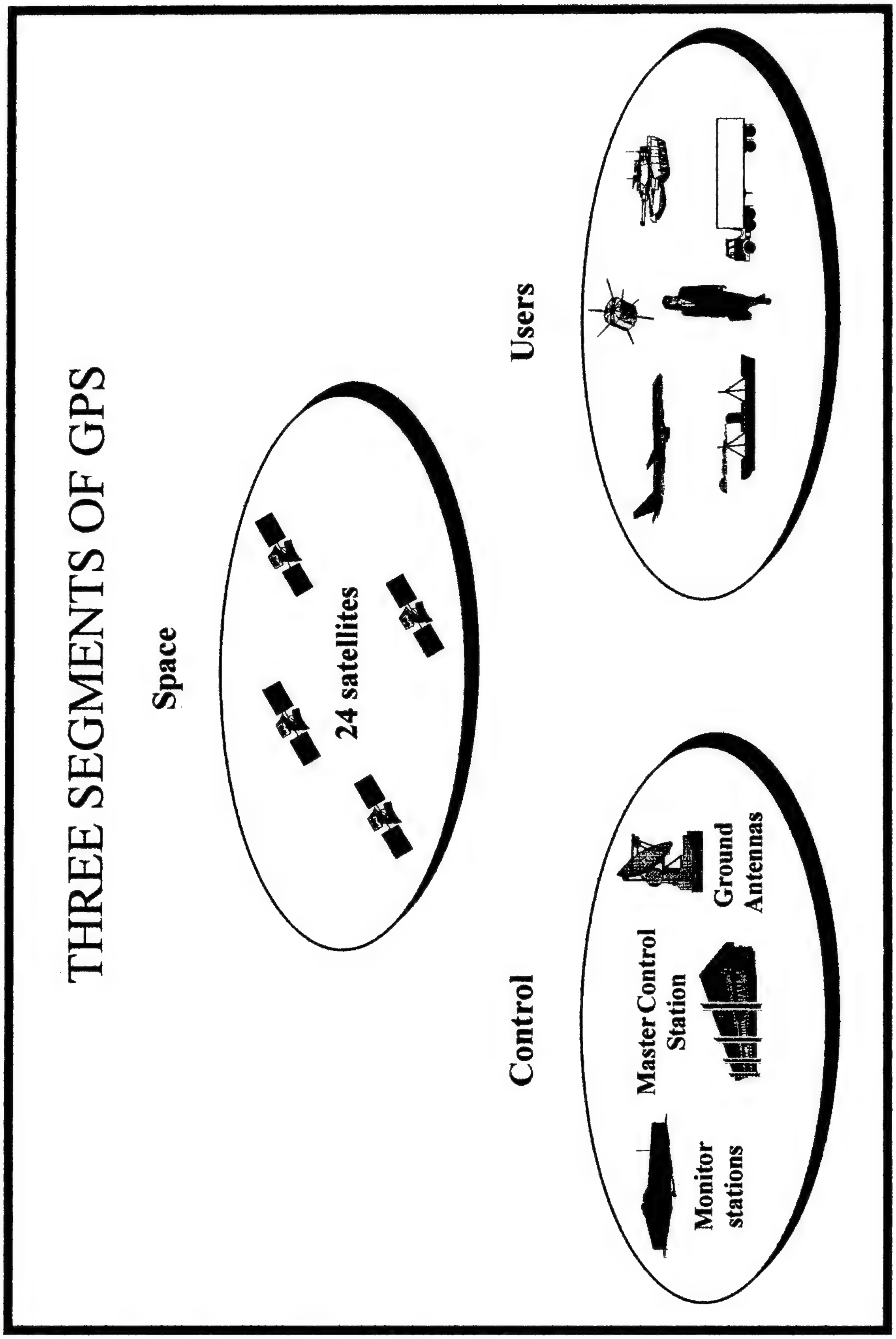
THREE SEGMENTS OF GPS
Space
24 satellites
Control
Monitor stations
Master Control Station
Ground Antennas
Users

Figure 3

Using triangulation techniques, GPS times how long it takes coded radio signals to reach the earth from its satellites. A receiver does this by generating a set of codes that are identical to those transmitted by the system's satellites. It calculates the time delay between its codes and the codes received from the GPS satellites by determining how far it has to shift its own codes to match those transmitted by the satellites. This travel time is then multiplied by the speed of light to determine the receiver's distance from the satellites. A GPS receiver could, in theory, calculate its three-dimensional position by measuring its distance from three different satellites, but in practice, a fourth satellite is necessary because there is a timing offset between the clocks in a receiver and those in a satellite. The fourth measurement allows a receiver's computer to solve for this timing offset (Pace, 1995).

While satellites can be attacked, they are not easy targets. Therefore, developers must consider jam-resistant and survivability capabilities. The GPS satellites transmit two different signals for just this reason: the Precision or P-code and the Coarse Acquisition or C/A code. The P-code is designed for authorized users, including U.S. military forces, allies, and selected civilian organizations and companies. It is more accurate than the C/A-code and is more difficult to acquire and jam. To ensure that unauthorized users do not acquire the P-code, the United States can implement an encryption segment on the P-code called anti-spoofing.

The C/A-code is designed for use by nonmilitary users and provides what is called the Standard Positioning Service. The C/A-code is less accurate and easier to jam

than the P-code. It is also easier to acquire, therefore, military receivers first track the C/A-code and then transfer to the P-code.

In the early stages of development, numerous skeptics voiced their concern that the satellites were too vulnerable. There was also concern over what measures could be taken to prevent an enemy from using the GPS against the United States. Developers responded by introducing satellite timing and position errors into the satellite transmissions, a process that intentionally degrades the accuracy of GPS signals available to civilian users. This technology, called selective availability, still permits accuracy adequate for navigation purposes, but not for weapon delivery. These artificially imposed errors are to be removed for authorized U.S. and allied users only during war, or as stipulated by the President of the United States (Getting, 1993).

2.5.2.2 Aspects of GPS

GPS functions 24 hours a day, in all weather conditions, all over the globe, unhindered by stretches of water or desert, and unblocked by terrain, such as tall buildings or heavy foliage. Moreover, GPS services remain free, with the DoD absorbing the costs of launching and operating the satellites. Still, not all users or providers of satellite-based tracking systems partake of this service. Instead, some opt to purchase and launch their own satellites, or to simply lease channels on existing commercial satellites.

Perhaps the most common explanation for satellite tracking users to decline the free use of GPS is the concern that they could become too dependent on the military

satellite service, only to be "cut off" unexpectedly should a national incident cause access to the GPS to be limited. In this case, should selective availability be turned on, the GPS signal accuracy for civilian users is degraded to 100 meters, or 328 feet. The military, on the other hand, will still have the ability to track an asset to within 10 meters, or 33 feet. Furthermore, there is concern that the government may eventually decide to recoup some of its $10.5 billion investment by charging user fees (Moorman, 1993). For whatever reason, many users prefer to have control over their systems, rather than free access to a government-owned and operated system.

To combat the DoD's decision to decrease the accuracy of the C/A-code, civilian users (to include several federal agencies) pushed for the commercial development of a technique known as differential GPS (DGPS), a method of operating GPS that allows a user to obtain extremely high accuracies while circumventing the effects of selective availability. Specifically, a receiver is placed at a surveyed location, that is, a location whose position is known precisely. The GPS signals that arrive at that location contain errors that offset the position of the surveyed point by some distance. The errors in the GPS signal are determined by comparing the site's known position with its position according to GPS. Correction terms can be calculated and transmitted to users. Those correction terms allow a user's receiver to eliminate many of the errors in the GPS signal. Instead of 100 meter selective availability accuracy, DGPS users can plot their locations to within 3-10 meters, depending on the type of DGPS approach used (Lachow, 1995).

Differential GPS's greater accuracy is potentially useful in such ways as improving the accuracy of maps, enhancing search and rescue efforts, improving navigation in crowded waterways, and helping planes land in bad weather. One of the first federal applications of DGPS was a system installed by the U.S. Forest Service in 1988 for managing forest resources. While use of differential GPS in both the government and the private sector has mushroomed since that time, GPS industry officials estimate that about 95 percent of the market remains untapped (Government Accounting Office, 1994).

Use of DGPS is more reliable and much less expensive than traditional surveying methods. Growth is therefore expected in such activities as highway construction and mass transit applications. Furthermore, the National Park Service, the U.S. Fish and Wildlife Service, and other federal natural resource agencies plan greater use of DGPS for mapping and various natural resource inventory activities. With differential GPS services in such great demand, and since the technology is now available worldwide, the debate over whether or not selective availability should be left "on" seems pointless. Rather than waste time on this issue, the Army should begin preparing to operate in a world where access to GPS-type and augmented GPS services are the norm. An extensive infrastructure, realistic training, and a doctrine that combines GPS information with other systems must be developed if GPS is to be effective.

2.5.2.3 GPS and the Military

The Army's fiscal resources have declined substantially over the past several years and are expected to continue to do so into the future, resulting in a smaller force. Consequently, the Army must optimize the value of each and every dollar to ensure a competitive edge in warfare. Additionally, the Army needs to be more selective in determining which systems and technologies to pursue in order to hedge against the unknown and to ensure that they develop only capabilities not already available from other DoD activities. Satellite-based communications systems is just one way to enhance the Army's operational effectiveness and mitigate the impact of a smaller force (U.S. Army, 1995b).

Within the scope of satellite-based communications systems, the Global Positioning System is a technology capable of providing that needed competitive edge in warfare. GPS provides three major benefits for land-based military operations: self-location accuracy, navigation, and target location. In addition to its high accuracy, GPS allows users to determine their location passively, that is, users can find out where they are without transmitting any signals that could be detected and targeted by enemy forces. Improved self-location information can also reduce fratricide (unintentional attacks on one's own forces) if it is processed effectively, which depends on the command, control, communications, and intelligence (C^3I) capabilities of a given military.

GPS had its wartime debut during the Persian Gulf War, allowing American soldiers to plot safe lanes through minefields without revealing such battlefield

preparation to the Iraqis. It was indispensable in navigation for both land and air forces moving through the featureless desert terrain, giving precise location on the battlefield, as well as precise time (for synchronization purposes). Furthermore, the "common grid" or specific mapping coordinates provided by GPS proved to be a tremendous asset for the opening attack of Desert Storm, in which U.S. ships, cruise missiles, and helicopters had to be coordinated to the exact minute.

The use of GPS for Operation Desert Storm was the first successful tactical use of a space-based technology within an operational setting. Particularly interesting, however, is that most of the GPS receivers had to be purchased commercially because not enough military-qualified receivers and equipment were available at the time. The Pentagon bought most of the GPS receivers used in the Persian Gulf from Trimble Navigation and Magellan Systems. These two companies became emergency suppliers, selling the Pentagon 10,000 and 3,000 receivers respectively (Pace, 1995). Additionally, family members in the United States supplied soldiers with small hand-held GPS units which were purchased off-the-shelf at sporting goods stores and the like. Since almost ninety percent of the GPS receivers used in the war were of the commercial sort, the Defense Department could not activate the selective availability. Fortunately, the Iraqi forces possessed only a dozen or so GPS receivers themselves, so there was essentially no threat to American military users (Gregorian, 1993).

Since the Persian Gulf War, the United States has employed GPS in several peacekeeping and military operations. During Operation Restore Hope in 1993, GPS was

used to air drop food and supplies to remote areas of Somalia because of lack of accurate maps and ground-based navigation facilities. U.S. forces in Haiti in 1994 also relied on GPS. In each instance, selective availability was turned off because U.S. forces were still using commercially purchased GPS receivers.

Although there were no problems or incidents due to the non-use of selective availability during each of these operations, the Pentagon continues to believe that selective availability is essential to national security. So the debate over whether or not selective availability should be left on continues, and a growing number of commercial users actively lobby to leave selective availability off at all times. However, as previously mentioned, worldwide availability of DGPS essentially renders this argument pointless.

2.5.2.4 Commercial Uses of GPS

GPS was once described by the National Aeronautical Association as "the most significant development for safe and efficient navigation and surveillance of air and spacecraft since the introduction of radio navigation." (Getting, 1993) And although it originated in the defense sector, GPS is now considered one of the best examples of *dual-use* technology --- it serves both civilian and military users alike.

While GPS is not the first military system to provide substantial benefits to the civilian community (two notable examples are radar and the Internet), it certainly has the potential to make the most impact. The importance of GPS technology is becoming more

obvious as new applications are developed and many other applications are seeing GPS enhancements. Furthermore, it is predicted that in several decades GPS equipment may become as common as telephones and computers.

Commercial GPS markets include: marine, outdoor recreation, land-based professions, aviation, systems integration, and vehicle tracking/navigation. Currently, the outdoor recreation segment appears to be the biggest customer, due mainly to the reduced size and cost of GPS receivers: small hand-held units are now available for less than $500. Hunters, hikers, bird watchers, snowmobilers, treasure hunters and a host of other outdoor enthusiasts are finding GPS to be especially beneficial to their enjoyment of the great outdoors.

Vehicle tracking/navigation systems was the last market to evolve but it may very well be the single largest application for the technology, in terms of both unit volumes and sales revenue (White, 1994). From merchant vessels on the high seas to trucks on the Interstate, GPS already plays a major role in fleet management. Moreover, with roughly 300 million private passenger cars worldwide (and about 150 million in the United States alone), GPS is sure to impact many of us directly. Already in Japan, sales of the car-navigation system in 1995 were estimated at 530,000 (USA Today, 1996). In the United States the system is still somewhat of a novelty, offered only recently by luxury car dealers and several car rental agencies.

The U.S. Department of Commerce predicts that GPS will be a five-billion-dollar-a-year industry by the year 2000. This seems quite plausible, in light of recent estimates

which reveal that worldwide GPS sales rose from $20 million in 1989 to $121 million in 1992; in 1993, sales totaled more than $420 million (White, 1994).

2.6. Transportation and Fleet Management

2.6.1 Background

Fundamentally, a trucking firm must be able to deploy its equipment when and where a customer wants it. Furthermore, the equipment must be appropriate for the job, and the personnel involved must be trained in their duties. The appropriate equipment may include tractors, trailers, communications and tracking equipment, loading and unloading equipment, etc. Within most trucking firms, key personnel typically include dispatchers, managers, and drivers (LeMay, Taylor and Turner).

Since the mid-1980s, driver turnover has been a serious problem within the trucking industry. Deregulation, brought on by the Motor Carrier Act of 1980, permitted thousands of new companies to enter the market and enabled drivers to shop around for the best pay and benefits. As a result, companies continue to face driver shortages and increased driver turnover. Additionally, today's market is more competitive than ever before, with more trucks and trucking companies available than there are loads to carry. And as expensive as it is to keep a truck on the road (because of insurance, fuel, and fuel taxes), it's becoming increasingly difficult to make a profit, requiring carriers to be more responsive to consumer demands and to increase their product differentiation.

Research conducted by LeMay, Taylor and Turner (1993) revealed that several issues adversely affect driver retention: pay and benefits, personnel policies, the relationship between a company and its drivers, and working conditions, such as the age of the fleet. Surprisingly, driver turnover was found to be more positively related to the age of the fleet than to pay and benefits. That is, research shows drivers are more interested in having newer, more state-of-the-art equipment than they are in increased pay and benefits. They are frustrated with dispatchers who leave them to sit idle for long periods of time, awaiting instructions on the next assignment. Drivers believe that more advanced technology, such as satellite-based communications systems, will alleviate their frustrations and keep them behind the wheel (rather than on the phone), allow for increased productivity, and ultimately result in more pay, since their pay is typically based on road miles.

A factor which contributes to productivity, *time* is a primary concern in the trucking industry. If a delivery is late, it can cost a company a considerable amount of money and impact its credibility with customers. Therefore, choosing some system of mobile communications is a necessity for a large fleet operator to remain competitive in an industry where time spent on the road is money --- and a lost, stranded, or empty truck generally translates into lost revenue.

Being able to communicate with the dispatcher not only brings increased job satisfaction to the driver, but also eliminates the many hours that he wastes searching for a pay phone, hoping to get through to the dispatcher to receive directions for the next

pickup. Mobile communications allow carriers to respond to fast service calls and requests for just-in-time (JIT) deliveries, and also provide drivers with the ability to inform their companies of breakdowns, emergencies and delays.[15]

2.6.2 Commercial Uses of Satellite Tracking

Satellite-based communications systems have revolutionized the trucking industry by bringing higher morale to the drivers and increasing productivity for the trucking firms. Previous solutions to vehicle communications such as cellular phones, beeper devices and radio transmitters do not provide the same geographic coverage, which is a significant drawback of these technologies. But technical advances in digital transmission via satellite have extended coverage to encompass the entire globe and have significantly reduced the total cost of operation. Other advantages of this technology include the ability to track stolen vehicles, the ability to transmit an emergency message with the push of a button, the ability to monitor a driver's speed, and the ability to communicate last minute instructions. The disadvantage is that, unlike cellular systems, the system transmits only data, not voice. Still, the digital data provided by satellite-based systems is faster, more accurate, more dependable, and less susceptible to eavesdropping.

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[15] Just-in-time deliveries are characterized by the frequent transport of goods in small quantities, resulting in minimal inventory levels. Suppliers must anticipate the buyers' needs, thereby reducing response time and its variability.

One common scenario for a firm equipped with satellite-based communications is a truck on a cross-country run that can be contacted by central dispatch to alert the driver to an unscheduled pick-up en route. The driver can immediately accept or reject the pick-up. Likewise, a driver about to deliver a load can signal his upcoming availability several hours before drop off. Central dispatch can search for the nearest pick-up and have a new load assignment ready by the time the truck is empty. This "pre-dispatching" maximizes truck productivity and reduces "deadhead miles," or the distance an empty truck has to travel to reach another pickup or home base.

Johnnie Bryan Hunt, majority owner of J.B. Hunt Transport Services, Inc., was one of the first within the trucking industry to recognize that higher employee satisfaction (and lower turnover costs) could be achieved through technology. Hunt reasoned that if his employees were happy, productivity would therefore increase. He incorporated mobile communications technology and developed an information system to facilitate the more effective scheduling of equipment and drivers. As a result, Hunt has been able to run his trucks 126,000 miles per year, as opposed to an industry average of about 115,000. More importantly, Hunt's trucks run loaded 92 percent of their miles compared to an average of 88 percent for his competitors, while the base pay of Hunt's drivers is roughly comparable to that in other firms. As for driver turnover, management at Hunt Transport Services estimates that a reduction of five percentage points in its annual rate would be worth $1 million in reduced training costs alone (Heskett, 1990).

In addition to decreased driver turnover rate, satellite-based communications also permit Hunt Transport Services to book up to 10 percent more miles per day, with fleet managers handling 20 percent more trucks. Daily driver-dispatcher phone contact has been reduced from two hours to 15 minutes, and the savings on the 21.5 million transmissions that flash through the system each year are significant, since wireless transmissions cost only an average of 20 cents apiece, as opposed to several dollars for a typical phone call. Such savings are made possible because satellite communication providers bill by message unit and by the number of characters, and J.B. Hunt uses mostly customized, pre-programmed messages where icons or characters stand for commonly used words and phrases. Such a system makes communicating easier for the drivers and reduces overall costs. Additionally, unlike cellular service, there are no sign-on fees with satellite-based communications when traveling from one region of the country to another (McCarthy, 1996).

2.6.3 Satellite Tracking Literature Flourishes

As mentioned previously, companies that use the government-owned and operated GPS need not fear the loss of communications due to bad weather or dense terrain because of the numerous satellites that support the system. However, companies that rely on other satellite systems that do not have as much back-up capability may encounter problems or disruptions in service. For example, meteor bursts may interfere with transmissions and high winds can jostle the big central terrestrial dishes, which may

result in a loss of data. But according to Schneidermann (1989), such occurrences are relatively infrequent.

The most significant obstacle to wireless satellite-based communications seems to be its incompatibility with wired corporate systems. Companies that have computer and communications systems already established must find a way to make the satellite system compatible. While the cost of the equipment has discouraged some fleets owners, many carriers are nonetheless pressing ahead to put the new technology to work. In fact, a number of fleet executives say that the ability to provide customers with more timely information on shipments has brought them new business. According to one estimate for a $200 million middle-market company, a mobile data network may cost between $500,000 and $3 million. But even at these prices, a number of large and small businesses say they were able to recoup their investments in 18 to 36 months (McCarthy, 1996).

Given the need for specialized hardware and software, a number of companies have evolved to meet this need, and to make satellite-based communications systems appear more attractive and less obtrusive. Irwin Jacob's Qualcomm Corporation has established an early lead in the industry, producing a popular hardware system called OmniTRACS, the purpose of which is to permit trucking dispatchers to know the general location of every member of the fleet. This knowledge helps to minimize the number of empty loads as trucks that discharge their cargo can be instantly notified to make a new pickup in the same area. Qualcomm Corporation is considered a one source supplier since

it not only manufactures the hardware but also provides the actual communications service between trucks and fleets (Cross, 1991).

Regardless of the brand name, the typical space-based system consists of three key components:

(1) Ruggedized portable computers with keyboards and antennas on mobile units, which send and receive messages to-and-from the satellite and vehicle.

(2) Transponders, or satellites, complete with backup capability to guarantee operational redundancy.

(3) A Network Management Facility (NMF), through which all transmission traffic is routed. From here, data from mobile units are sent via terrestrial lines to fleet operations centers.

Most satellite-based mobile communications systems work on the same general principle: once turned on, the system runs through a search routine to locate the satellite signal (see Figure 4). The dispatcher can contact a truck anywhere by sending a message from the fleet operations center via a standard telephone line to the network management center (located within the NMF), which is typically operated by the satellite system provider. Once the information traffic is processed, it is transmitted via the uplink facility to the satellite. The message is broadcast nationwide and received and acknowledged by the targeted vehicle. As a point of reference, Qualcomm claims that it

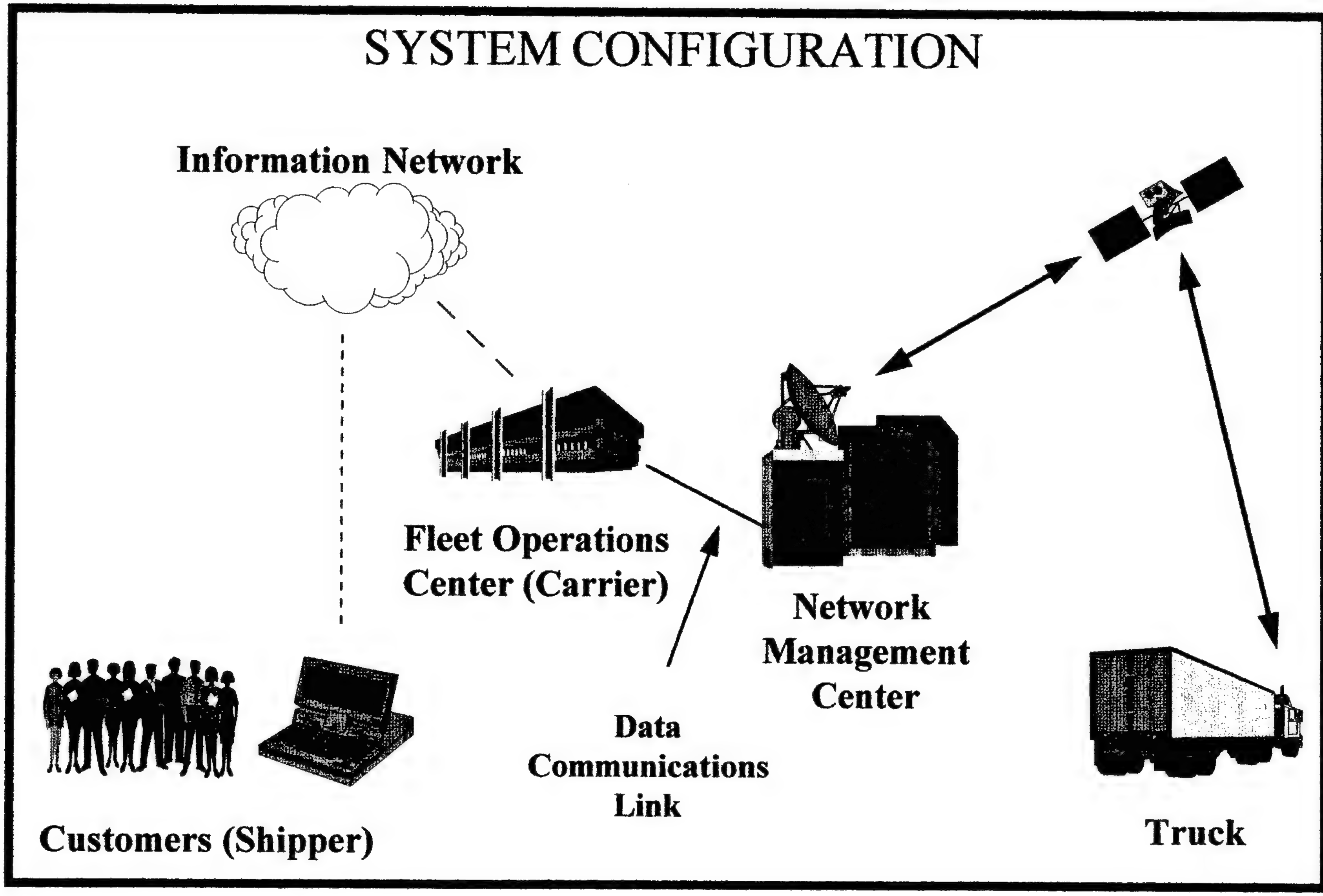
SYSTEM CONFIGURATION
Information Network
Fleet Operations
Center (Carrier)
Network
Management
Center
Data
Communications
Link
Customers (Shipper)
Truck

Figure 4

takes 15 to 30 seconds for a message to pass from driver to dispatcher, but less than 5 seconds to pass from dispatcher to driver. Furthermore, Qualcomm's mobile units are "frequency agile," meaning that if service should have to switch to a backup transponder or satellite, the vehicle's directional antenna will adjust itself to continue sending and receiving transmissions without downtime (Siegel, 1990).

Since the technology, though considered state-of-the-art, has been employed by various trucking firms for practically a decade, costs have substantially decreased and the number of service providers and hardware/software manufacturers have increased. Among the companies that act as service providers, a small number use the government owned and operated Global Positioning System, but the majority use commercially launched satellites. The three largest providers of GPS services are Rockwell International Corporation, Trimble Navigational, and Magellan Systems. Qualcomm Corporation, the overall leader in the industry, uses its own commercially launched satellites.

Prices for satellite-based communications systems vary according to the applications sought, but the basic hardware and software are pretty close in price whether using a GPS provider or a commercial satellite provider (see Table 1).

Table 1

Price Comparison of GPS Providers versus Commercial Satellite Providers			
	Price of mobile hardware	**Price of basic software**	**Usage fee (per month)**
Qualcomm's OmniTRACS	$4,500	$ 3,000 - $25,000	$35 (minimum)
Rockwell's Pro2000 (GPS)	$4,000	$10,000 - $20,000	$45 - $55

Hardware comes in various forms (display maps, touch screens, key boards, etc.) and software can be as basic or as complicated as fits a carrier's needs. A company considering the purchase of satellite-based technology should do its homework and consider all of the options. Christine White (1995) offers the following advice for first time buyers:

1. Build on your existing computer and software systems - find the software you want to use and then buy hardware that can run it. If your company already has computers, find a system that is compatible with the existing systems.

2. Be aware of the costs of different levels of systems - get a system that matches your current and expected needs. Companies with different goals will have different needs. (For example, transporters of hazardous or sensitive cargo may need a system with increased security or safety measures.)

3. Look at a system in action before committing to using it - all service providers and hardware/software manufacturers provide demonstrations and "test drives."

4. Expect initial resistance from drivers until they experience the benefits firsthand - several companies report that while drivers initially considered the system an invasion of their privacy, the real-time value of the system quickly became apparent.

> 5. Prepare to use the new flexibility to your advantage - stay on top of new applications as they continue to evolve. The most recent additions to applications include: the ability to fax lading bills from the truck cab to the fleet center, automatic driver log updating, the tracking of maintenance problems, and the monitoring of a driver's speed.

As satellite-based communications technology becomes more accepted and less of a "bells and whistles" type of option, the prices for the systems and the service will continue to drop. Already, the costs for this technology have been proven less expensive than cellular technology. Indeed, firms that may have tested satellite-based communications systems in the past will be surprised to find how cheap the systems have become, and should consider another look at the technology. Moreover, as the implementation of satellite-based communications systems grows, it will become a "standard" service to shippers, and firms that do not implement processes that utilize this type of service will find themselves at a competitive disadvantage.

2.7. Summary

Within the transportation industry, trucks are more vulnerable than other modes to disruptions stemming from mechanical failure, accidents, local traffic delays, and adverse road conditions. They are also more prone to frequent changes in routing and scheduling. Therefore, the tracking of a truck fleet is practically a requirement if a company wants to maintain a competitive edge in landing and retaining core accounts. The state-of-the-art technique for this emerging need is a two-way mobile satellite communications system

which enables fleet control centers to (1) pinpoint the location of each mobile unit; (2) send and receive messages to and from the truck drivers; (3) and monitor the status of tractor/trailer operating parameters.

Trucking firms which use satellite-based communications technology have derived several benefits from their investment. For example, major cost savings have come from increased equipment utilization and load ratio (the ratio of loaded miles to total miles). Decreases in out-of-route miles and driver telecommunications expenses are also significant. Other benefits include: increased driver quality of life, customer service, and safety, as well as decreased insurance charges, fuel consumption, driver turnover and overall staffing. However, the overriding benefit may be one of improved information quality in the important communications link between the truck driver, terminal operations and the shipper.

Chapter 3

SURVEY METHODOLOGY

3.1. Introduction

A survey questionnaire was sent to 498 Continental United States members of the American Motor Carrier Association (AMCA) to elicit ideas pertaining to the benefits of satellite-based communications and tracking systems. For the purpose of this research, the AMCA was chosen from the numerous existing trucking associations based upon the availability of its membership list to this researcher, as well as the fact that the list was more recent than those of other associations. Since trucking firms have a tendency to enter and leave the market so rapidly, it was felt that using the most recent publication would result in the best response rate.

The directory of AMCA members did not reveal the size of the firms or the type of service each firm provided, whether less-than-truckload, truckload, etc. Furthermore, there was no way of knowing which of the members use satellite-based tracking technology. Consequently, the sample size had to be large in order to ensure an adequate response rate.

The questionnaire allowed for input from those members of the Association whose companies do not presently use satellite tracking systems. The package included a cover letter, a copy of the survey, and a postage-paid return envelope. Confidentiality

was maintained by coding each questionnaire. However, companies not using satellite tracking could be identified by the codes for possible future research.

In order to ensure that the surveys were indeed answered by someone within each firm who had knowledge of his or her firm's day-to-day operations and overall mission or strategy, all envelopes were addressed to the "Operations Manager." Additionally, the cover letter that accompanied the survey requested that the receiver pass the survey along to someone else within the firm if they themselves were unable to adequately answer the questions.

Data were collected on the following perceived benefits of satellite-based tracking systems: time savings, increased productivity, improved customer service, and increased return on investment (ROI). Also, questions were asked regarding the number of years a company has used satellite-based tracking systems, and the percent of a company's fleet that is currently equipped with satellite tracking hardware. For those firms not yet employing the technology, space was provided for a brief explanation as to why the company does not use the technology (see Appendices A and B).

Twenty-nine of the surveys were returned as undeliverables, reducing the effective sampling size to 469. Following a second mailing, a total of 113 responses were received, resulting in an effective response rate of 24 percent. Of the 113 responses, twenty-eight completed the survey questions regarding perceived benefits and eighty-five explained that they do not presently use satellite-based technology. The various reasons for this non-use are included in Chapter 5.

3.2. Structure Model

The dependent variables, twenty in all, can be found at Figure 5; they are abbreviated in the structural model (see Figure 6), where the performance measures and constructs are also provided. It is expected that all measures and constructs will have a positive impact on a firm's decision to purchase satellite-based technology.

VARIABLE	WORDING
T1	more time spent behind the wheel
T2	more timely reporting of maintenance problems
T3	drivers locate addresses more quickly
T4	before satellite technology, drivers lost time
T5	less time spent trying to call dispatcher
P1	little change in number of deliveries
P2	fewer "dead miles"
P3	re-routing of drivers permitted
P4	truck utilization is maximized
P5	drivers favor systems
C1	customers are better serviced
C2	customers seek out carriers
C3	customers have more control
C4	systems allow greater visibility
C5	systems provide flexibility
R1	holding costs decrease
R2	labor costs decrease
R3	customer demand increases
R4	telephone costs decrease
R5	driver turnover decreases

Figure 5

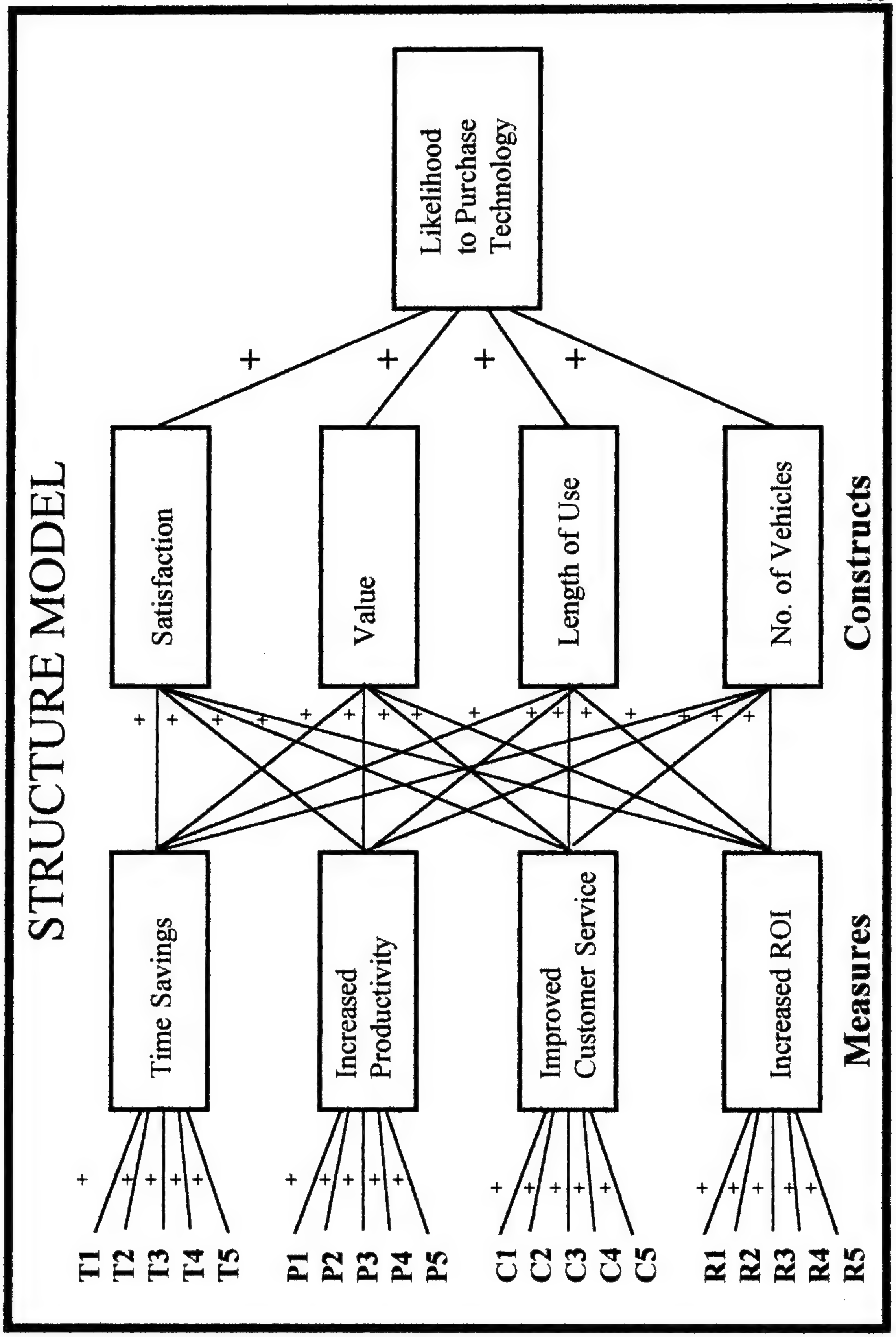
STRUCTURE MODEL
Likelihood to Purchase Technology
+
+
+
+
Satisfaction
Value
Length of Use
No. of Vehicles
Constructs
Time Savings
Increased Productivity
Improved Customer Service
Increased ROI
Measures
T1
T2
T3
T4
T5
P1
P2
P3
P4
P5
C1
C2
C3
C4
C5
R1
R2
R3
R4
R5

Figure 6

Chapter 4

RESULTS AND ANALYSIS

4.1. Introduction

Regression analysis was used to describe the relationship between time savings, increased productivity, improved customer service, and increased ROI, on the response variables: satisfaction, value, length of use, and percentage of fleet using satellite-tracking technology. The purpose of the analysis was to identify significant factors for each response variable and to predict which factors would most positively influence an organization to purchase satellite-tracking technology.

The general linear regression model for more than two independent variables was used (Neter, 1990) :

$$Y_i = \beta_0 + \beta_1 X_{i1} + \beta_2 X_{i2} + \beta_{p-1} X_{i,p-1} + \varepsilon_i$$

where:

Y_i is the observed response in the i^{th} trial
$X_{i1}, \ldots, X_{i,p-1}$ are known constants, the level of the independent variables in the i^{th} trial
$\beta_0, \beta_1, \ldots, \beta_{p-1}$ are parameters
ε_i is an error term independent and normally distributed, $N(0, \sigma^2)$
$i = 1, \ldots, n$
$X_{i0} \equiv 1$

The error term was assumed to be normally distributed and represented the effects of any factors excluded from the model. Additionally, the testing and estimation procedures

used were based on the t distribution, which is not sensitive to moderate departures from normality (Neter, 1990).

4.2. Hypotheses and Evaluation Criteria

The examined hypotheses are restated below:

$H_{0,1}$: The time savings resulting from the use of satellite tracking systems will positively impact the decision to purchase this technology.

$H_{0,2}$: The increased productivity resulting from the use of satellite tracking systems will positively impact the decision to purchase this technology.

$H_{0,3}$: Improved customer service resulting from the use of satellite tracking systems will positively impact the decision to purchase this technology.

$H_{0,4}$: Increased return on investment (ROI) resulting from the use of satellite tracking systems will positively impact the decision to purchase this technology.

There are three general selection criteria. First, any linear regression must pass the global F-test, or lack of fit test. The purpose of this test is to ascertain whether the regressed line significantly represents (fits) the data. Second, the coefficients of variables must be significantly different from zero. Third, the assumption of the general linear model must be met. If this assumption is met and the model passes the general F-test, then inferences can be made about the data. That is, if any of the independent X variables (Time Sav, Incr Prod, Impr Cust Svc, or Incr ROI) significantly enter a regression model and the three general selection criteria are met, inferences can be made on the four

hypotheses above. If not, there is no support (variables do not enter the models) and the hypotheses can be neither accepted nor rejected; a new model would be needed.

4.3. Statistical Methodology

The survey data for respondents using satellite-based tracking systems is included as Appendix C. Of the one hundred and thirteen responses to the survey, only twenty eight firms (24.77% of respondents) claim that all or portions of their truck fleet use satellite tracking technology. Such a small sample size is typically analyzed using non-parametric regression techniques, however, the large number of non-using firms (which represent the customer population for this study) demonstrates the large population necessary for parametric analysis. Additionally, since the intention is to make limited predictive conclusions for a population presumed to be normally distributed, parametric regression will have more greater predictive strength than non-parametric procedures. Later discussions will show certain difficulties meeting the assumptions of the general linear reqression model. One problem of note was non-independence of the error terms from response or independent variables. Non-parametric procedures, while not requiring normally distributed error terms, do assume that error terms are identically and independently distributed. Non-parametric analysis would not overcome the independence problem. Consequently, parametric regression techniques were used for this analysis.

The first step in identifying a relationship between any or all of the independent variables and the response variables was to examine the correlation of each response variable with the independent variables. By doing so, it was possible to determine whether the independent variables were truly independent or if significant correlation existed. Furthermore, the degree of correlation dictated the model building procedure that was appropriate. That is, since significant correlation precluded the use of a step-wise procedure, each model had to be built manually, one variable at a time, using the extra sums of squares to identify those variables that provided the greatest reduction in random error. The extra sum of squares measured the marginal contribution of a particular variable to increasing the regression sum of squares or, conversely, in reducing the error sum of squares. Properly built multiple regression models (whether built by standard linear regression, step-wise or manual procedures) demonstrate a decreasing reduction in the error sum of squares. Improperly built models show larger reduction in error sum of squares for variables entered later in the model.

The correlation coefficient was calculated for each variable pair using the Pearson product moment procedure (MINITAB 10xtra Reference Manual, 1995). MINITAB calculated the correlation coefficient for all complete data pairs; missing data did not contribute to the coefficient. If significant correlation was evident (model would suffer from multicollinearity) then interaction terms would have been added as candidate variables in the model.

Best Subsets Regression was used to efficiently identify the combination of variables that would provide the best relationship between independent variables and the response variable. Best Subsets is only a screening procedure, as it does not identify optimal regression relationships. However, it is an effective time-saving device when certain conditions are met, the most important being that multicollinearity is not present. MINITAB then used a procedure called the Hamiltonian Walk to analyze all possible variable combinations and tabulate results in four selection criteria: coefficient of multiple determination (R_p^2), adjusted R^2, the C_p criterion, and error sum of squares (*s* or SSE_p), which varies inversely with R_p^2 (MINITAB 10xtra Reference Manual, 1995). Candidate variable subsets were identified which minimized the number of variables in the model (to simplify relationships and improve clarity of analysis), maximized the adjusted coefficient of multiple determination, and generated C_p values less than the number of variables in the model.

The C_p criterion assessed the total mean squared error of the fitted value for each subset and included a bias component and a random error component. The C_p was calculated using the equation:

$$C_p = \frac{SSEp}{MSE(X_1, \ldots, X_{p-1})} - (n - 2p)$$

where SSEp is the error sum of squares for the fitted subset regression model with p-1 predictor variables (Neter, 1990). The intent was to identify subsets with a small C_p criterion value near p. This occurs when the total mean square error is small. This

technique is vulnerable to multicollinearity and cases where a large bias component exists; therefore, it is important to identify only relevant variables for the technique to be effective. The best subsets regression technique suffers when multicollinearity is a problem; in such cases, the model needs to be manually built. The best subsets technique offers only a starting point for this process and may not correctly identify optimal variable combinations.

The two-sided t-test used to evaluate significance of individual variables was valid only for the last variable entered into the model. The formal t-test for significance for a particular β_k coefficient has the form:

$$H_0 : \beta_k = 0 \qquad\qquad H_a : \beta_k \neq 0$$

A test statistic t^* is calculated as $b_k \,/\, s\{b_k\}$. A particular β_k is determined to be significant by rejecting the H_o when $| t^* | > | t_{(1 - \alpha/2\,;\, n-2)}|$. A 95% confidence level was used whenever possible and corresponds to $\alpha = 0.05$. A particular β_k can be determined as significant directly from the P-value.

"The p-value for an outcome is the probability that the sample outcome could have a value more extreme than the one when $\mu = \mu_0$." (Neter, 1990) A low P-value (one less than the α-level) permits the analyst to determine significance directly. Consequently, the P-value was used as the primary diagnostic for significance of a particular β coefficient.

Other diagnostics conducted on all multiple-regression models constructed include the experimental lack of fit test (XLOF) and the Variance Inflation Factor. The experimental lack of fit test does not need replicates and determines the nature of any lack of fit by attempting to fit terms with curvature to the test equation. If curvature terms enter the model, there is evidence of a lack of fit.

The variance inflation factor (VIF) is a formal method to identify the presence of multicollinearity. This factor measures the degree of variance inflation of the estimated regression coefficients compared to when independent variables are not linearly related. When a variable is not linearly related to another variable, the VIF factor is 1.0. A maximum VIF greater than 10 indicates that multicollinearity is unduly influencing the least squares estimates (Neter, 1990). Values less than 5 are typical.

Upon completion of model building, the regression equation was formally tested for lack of fit and the coefficients were tested for significance. Finally, using residual analysis, model assumptions were tested and, when necessary, corrective measures were taken to obtain final models for each of the four response variables.

4.3.1 Model Construction

4.3.1.1 Satisfaction

The general model is adapted for the response variable *Satisfaction* as follows:

$$[\mathit{Satisfaction}]_i = \beta_0 + \beta_1 \mathit{TimeSav}_i + \beta_2 \mathit{IncrProd}_i + \beta_3 \mathit{ImprCustSvc}_i + \beta_4 \mathit{IncrROI}_i + \varepsilon_i$$

where,

Satisfaction$_i$ (Y_i) is the observed response in the i^{th} trial

TimeSav$_i$ (X_1), *IncrProd*$_i$ (X_2), *ImprCustSvc*$_i$ (X_3), *and IncrROI*$_i$ (X_4) are known constants, the level of the independent variables in the ith trial

β_0 , β_1 , . . . , β_{p-1} are parameters

ε_i is an error term independent and normally distributed, N (0 , σ^2)

i = 1, . . . , n

$X_{i0} \equiv 1$

The first step was to assess the correlation of candidate independent variables and the response variable *Satisfaction*. The critical value for Pearson's sample coefficient of correlation for $\alpha/2$ = 0.025 for sample size n=21 ($r_{21,.025}$) was 0.433 (Pearson and Hartley, 1966). The correlation matrix (extracted from MINITAB 10xtra output) is provided in Table 2:

Table 2

CORRELATION MATRIX OF INDEPENDENT VARIABLES

Correlations (Pearson) c.v. = 0.433

	X1 TimeSav	X2 IncrProd	X3 CustSvc	X4 IncrROI	
IncrProd	**0.737**				
CustSvc	**0.675**	**0.582**			
IncrROI	**0.808**	**0.507**	**0.649**		
Satisf	0.585	0.809	0.461	0.532	Response Variable

This matrix indicates that *all* pair-wise correlations are significant. The variables are not independent and interaction terms were added as candidates. The variables added were:

XXTSIP	(TimeSav / IncrProd interaction)
XXCSIP	(CustSvc / IncrProd interaction)
XXTSROI	(TimeSav / IncrROI interaction)
XXTSCS	(TimeSav / CustSvc interaction)
XXIPROI	(IncrProd / IncrROI interaction)
XXCSROI	(CustSvc / IncrROI interaction).
XXXTSIR	(Aggregate interaction term for all four variables)

The model could demonstrate significant multicollinearity if more than one variable was added to the model. Therefore, the best subsets and step-wise regression methods were not appropriate. Multicollinearity does not prevent the ability to obtain a good fit nor affect ability to make inferences about mean responses or predictions of new observations. However, these inferences must be made only within those data regions within the observational range of the model. The modified correlation matrix is shown in Table 3:

Table 3

MODEL 1: CORRELATION MATRIX

Correlations (Pearson)

	Satisf	TimeSav	IncrProd	CustSvc	XX_TSCS	XX_TSROI	XX_IPCS	XX_IPROI
TimeSav	0.585[7]							
IncrProd	0.809[1]	0.737						
CustSvc	0.461[8]	0.675	0.582					
XX_TSCS	0.638[5]	~~0.932~~	0.737	~~0.885~~				
XX_TSROI	0.608[6]	~~0.955~~	0.697	0.702	~~0.919~~			
XX_IPCS	0.788[2]	0.776	~~0.890~~	~~0.876~~	~~0.902~~	0.760		
XX_IPROI	0.729[4]	0.874	~~0.843~~	0.763	0.898	~~0.930~~	~~0.893~~	
XXXXTPSR	0.745[3]	~~0.898~~	~~0.851~~	~~0.810~~	~~0.950~~	~~0.929~~	~~0.921~~	~~0.972~~

Superscripted numbers indicate variable entry order based on strength of correlation with response variable (Satisfaction). Step-wise regression was not possible due to multicollinearity. Model must be manually built.

The model had to be built manually, one variable at a time, based on the methods of extra sum of squares. Variable entry order, as indicated by the superscripts under the *Satisf* variable column shown in Table 3 was based on the strength of the correlation between independent or interaction variables and the response variable. The complete model is:

Satisfaction = - 0.312 + 0.231 Increased Productivity

The final MINITAB regression report for the *Satisfaction* model is provided in Table 4:

Table 4

MODEL 1: FINAL REGRESSION ANALYSIS REPORT

```
Regression Analysis

The regression equation is
Satisf = - 0.312 + 0.231 IncrProd

25 cases used 3 cases contain missing values

Predictor        Coef       Stdev    t-ratio        p
Constant      -0.3117      0.6454      -0.48    0.634
IncrProd      0.23082     0.03501       6.59    0.000  p < 0.05 ∴ Signif. Var.

s = 0.5572       R-sq = 65.4%      R-sq(adj) = 63.9%

Analysis of Variance

SOURCE        DF          SS          MS          F        p
Regression     1      13.498      13.498      43.47    0.000
Error         23       7.142       0.311
Total         24      20.640

Unusual Observations
Obs. IncrProd      Satisf         Fit  Stdev.Fit    Residual    St.Resid
 28      10.0       3.000       1.997      0.307       1.003      2.16RX

R denotes an obs. with a large st. resid.
```

No significant additional independent or interaction terms could be added to the model. Therefore, the general multiple regression collapsed to a simple linear regression problem and was tested appropriately. The complete summary of model building for the *Satisfaction* response variable is included at Appendix D. Figure 7 shows the fitted line plot for *Satisfaction* versus *Increased Productivity*:

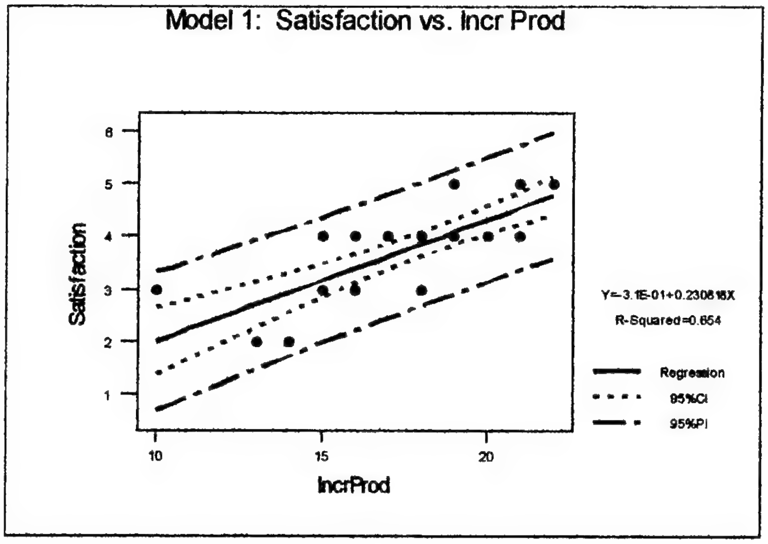

Figure 7

The solid line marks the fitted regression equation for the sample data. The dotted-line marks the 95% confidence interval for the line. The 95% CI means that there is a 95% likelihood that the true population relation is oriented within the area marked by the dashed lines. The 95% prediction bands (PI) means that the true orientation of a line in future studies will lie within the constraints of those bands. The Pearson correlation of *Satisfaction* and the *Increased Productivity* variable is stated as:

Correlation of Satisf and IncrProd = 0.809.

Correlation of response and independent variables is an additional diagnostic identifying the strength of the linear relationship. The formal correlation test is stated as follows:

Table 5

FORMAL TEST OF CORRELATION

$H_o: \rho = 0$	$H_a: \rho \neq 0$
If $\lvert r^* \rvert < \lvert r_{c.v.} \rvert$ Fail to reject H_0 If $\lvert r^* \rvert \geq \lvert r_{c.v.} \rvert$ Reject H_0, conclude H_a; correlation is significant	
$r^* = 0.809$ $r^* > r_{c.v.}$	$r_{c.v.} = 0.423$ Reject Ho, conclude Ha: $\rho \neq 0$

The critical value for $r_{25,\,025}$ ($\alpha/2 = .025$) was approximately 0.423 (Pearson, 1966). As indicated in the formal test, the correlation of independent and response variables was significant.

The residual plots shown in Figure 8 demonstrate that the residuals are normally distributed. MINITAB used the normal plot in lieu of the expected value plot. A normally distributed residual pattern is demonstrated by a nearly linear plot on the normal plot. Figure 8 displays an annotated normal probability plot.

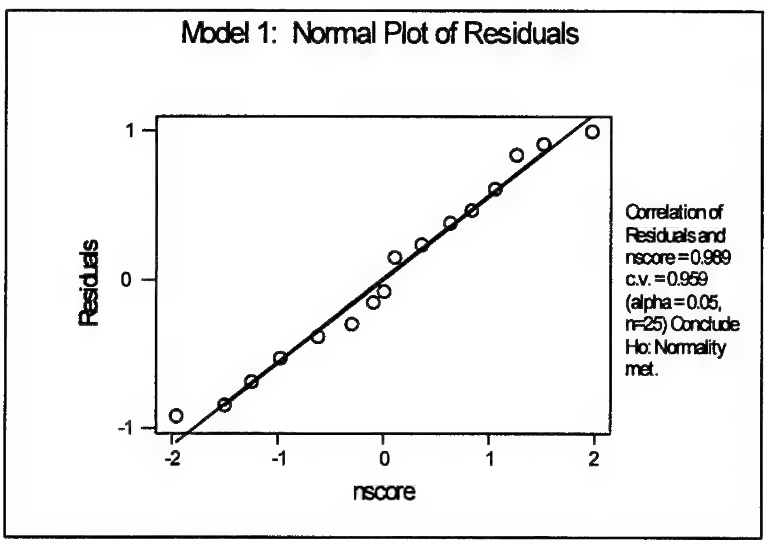

Figure 8

The points in Figure 8 fall reasonably close to the line obtained using linear regression of the residuals against the normal score or expected value when the distribution is normal. The correlation of the ordered residuals and the normal score is a one-sided test. The test statistic is 0.989, which is above the 0.959 critical value, marking the rejection region (Neter, 1990). Therefore, the error terms are normally distributed.

The histogram in Figure 9 demonstrates some skewness in the residuals but they still appear normally distributed.

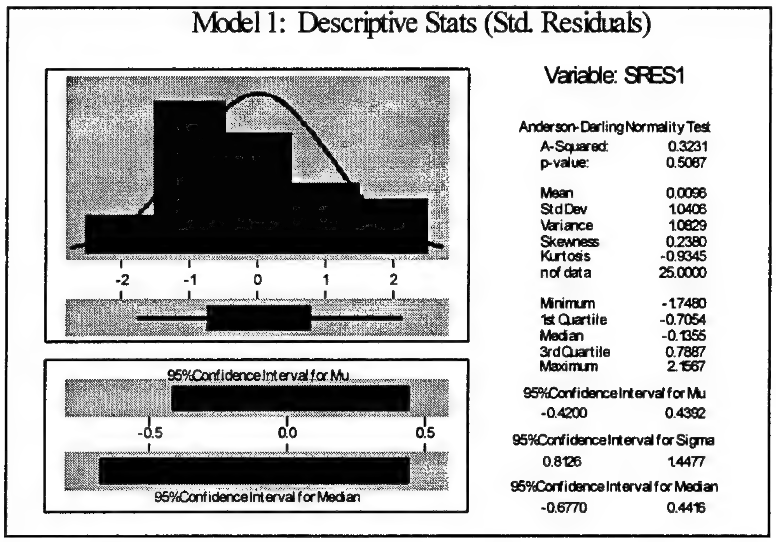

Figure 9

The box plot below the histogram demonstrates that the standardized residuals are positively skewed, but are without significant outliers.

Figure 10 shows the fundamental residual test:

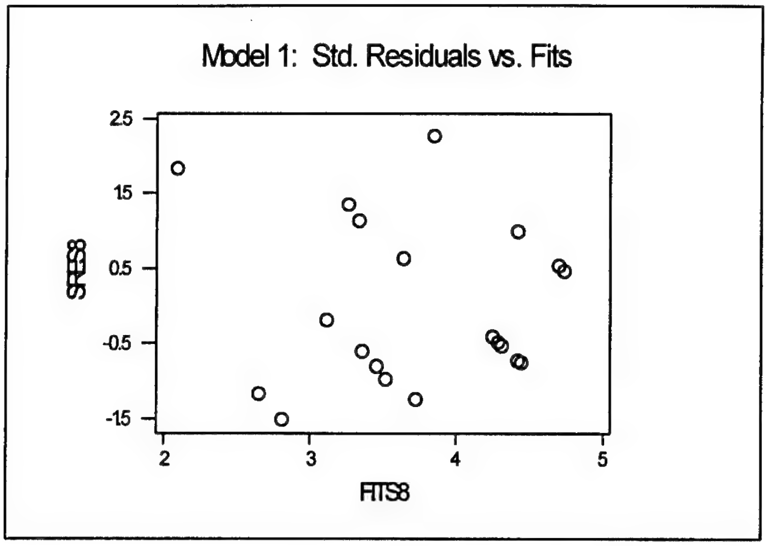

Figure 10

Figure 10 shows linear patterns which suggest that the error terms may violate the non-independence assumption. Ideally, the residual plots should show no distinctive pattern, should be uniformly distributed, and that variance is uniform throughout the plot. The residual plots permit visual assessment of constancy of variance (homescedasticity), independence of the residuals from response or independent variables, and assess the distribution of the residuals. When the residuals are standardized by dividing the normal residuals by the square root of the error mean square ($\sqrt{MSE}$), the residual plots also help identify any outliers as those outside two standard deviations from zero. In addition to the linear patterns, the plot also identifies one possible outlier outside two standard deviations (which corresponds to a 95% confidence level).

The standardized residuals were further plotted against the independent variable, *Increased Productivity*. This plot is shown in Figure 11.

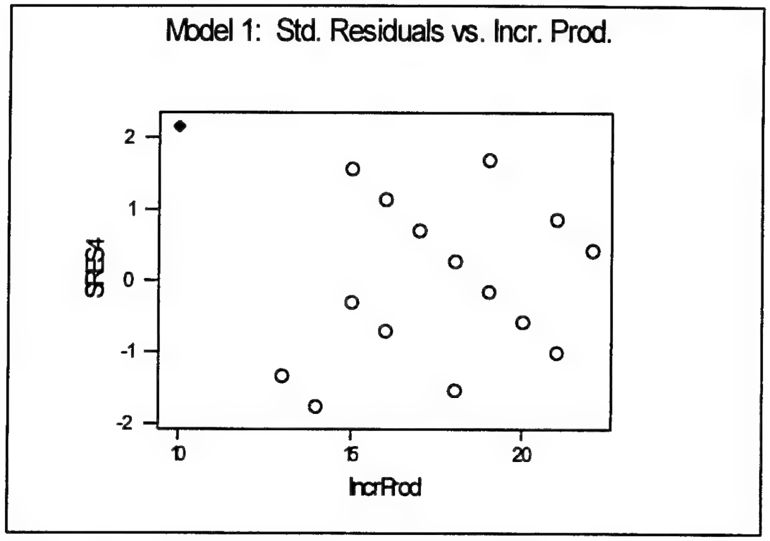

Figure 11

This plot shows the same linear patterns as the residual vs. $\hat{Y}$ plot. The residuals appear to be positively correlated to the independent variable. However, the plot demonstrates even distribution about the mean and only one point outside two standard deviations. The distribution does appear to be uniform as also indicated in the standard residual vs. $\hat{Y}$ plot. The apparent dependence on the independent variable may be due to the small range of the variable rather than a non-independence problem. Another possibility is a missing critical variable. However, no independent variable or interaction term could be added to the model. Figures 12, 13, and 14 plot standardized residuals against non-selected independent variables.

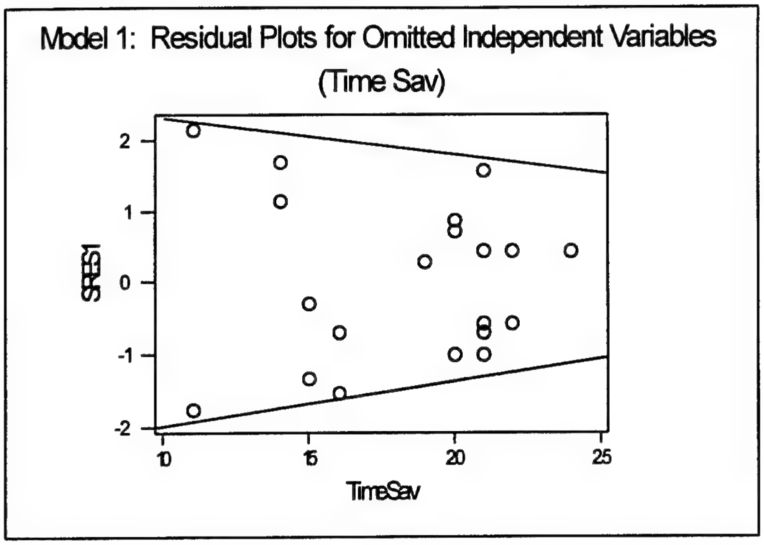

Figure 12

The residual / *Time Savings* plot (X_1) demonstrates a problem with fanning or non-constant variance. Certain transformations would be necessary to correct this problem had time savings been a significant addition to the model.

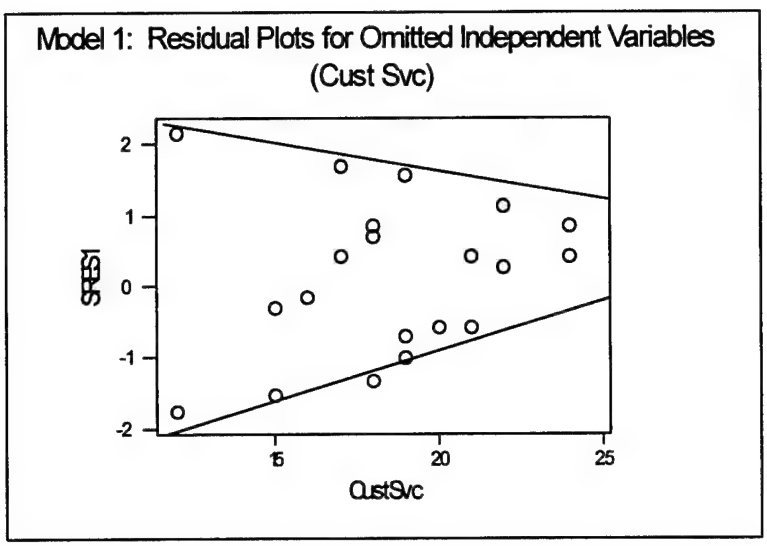

Figure 13

Comparable results are shown for the residual / *Customer Service* plot (X3). This plot shows an even more severe necking down of variance that would need transformations to correct. The residual / *Increased ROI* plot (X4) shows no such problem, and had the variable been significant, would not have needed any corrective actions.

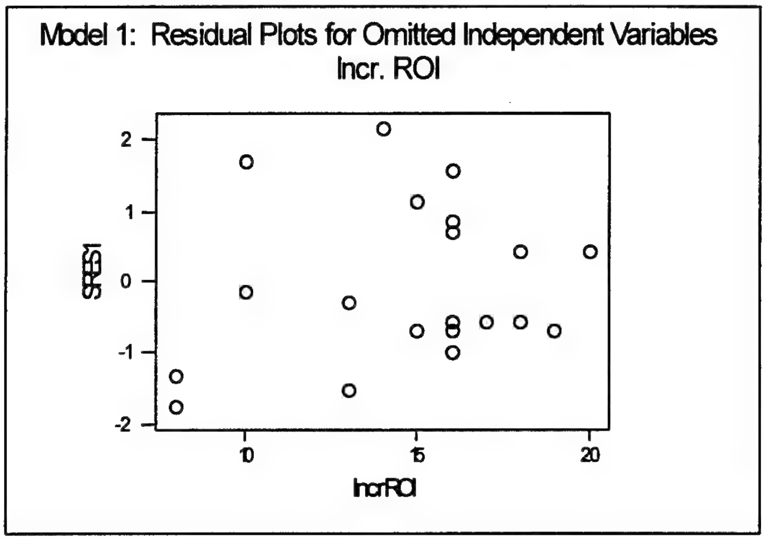

Figure 14

A complete MINITAB report showing the results of the model building effort is provided at Appendix D. No identified independent variable or interaction term could be added to the model. Consequently, any missing variable (e.g., size of firm) was not captured in the survey of Motor Carrier Association members.

A significant linear relationship exists between the response variable *Satisfaction* and the independent variable *Increased Productivity*. The re-stated model is:

Satisfaction* = - 0.312 + 0.231 *Increased Productivity

The model meets all assumptions of the general linear model save, possibly, for the non-independence of residuals assumption. Although the *Increased Productivity* variable appeared to be significantly correlated to other independent variables, those variables did not significantly reduce the random error of the model and could not be added. Multicollinearity does affect coefficients even if certain intercorrelated independent variables are not included in the model. The coefficient in this model will reflect the effects of other variables not expressly identified.

This model supports the second hypothesis. *Increased Productivity* positively effects *Satisfaction* and increases the likelihood to purchase the technology.

4.3.1.2 Value

The general model is adapted for the response variable *Value* as follows:

$$[Value]_i = \beta_0 + \beta_1 TimeSav_i + \beta_2 IncrProd_i + \beta_3 ImprCustSvc_i + \beta_4 IncrROI_i + \varepsilon_i$$

where,

$Value_i$ (Yi) is the observed response in the i^{th} trial
$TimeSav_i$ (X_1), $IncrProd_i$ (X_2), $ImprCustSvc_i$ (X_3), *and* $IncrROI_i$ (X_4) are known constants, the level of the independent variables in the i^{th} trial
$\beta_0, \beta_1, \ldots, \beta_{p-1}$ are parameters
ε_i is an error term independent and normally distributed, $N(0, \sigma^2)$
$i = 1, \ldots, n$
$X_{i0} \equiv 1$

The correlation of candidate independent variables and the response variable *Value* was determined. The critical value for Pearson's sample coefficient of correlation for $\alpha/2 = 0.025$ for sample size $n = 24$ ($r_{24,.025}$) was approximately 0.423 (Pearson and Hartley,

1966). The correlation matrix (extracted from MINITAB 10xtra output) is provided in Table 6:

Table 6

MODEL 2: CORRELATION MATRIX

Correlations (Pearson)

	Value	TimeSav	IncrProd	CustSvc	IncrROI	XX_TSIP	XX_TSCS	XX_TSROI
TimeSav	0.645							
IncrProd	0.727	**0.737**						
CustSvc	0.546	**0.675**	**0.582**					
IncrROI	0.591	**0.808**	**0.507**	**0.649**				
XX_TSIP	0.737	~~0.927~~	~~0.926~~	**0.666***	**0.755***			
XX_TSCS	0.698	~~0.932~~	**0.737***	~~0.885~~	**0.795***	~~0.891~~		
XX_TSROI	0.654	~~0.955~~	**0.697***	**0.702***	~~0.938~~	~~0.898~~	~~0.919~~	
XX_IPCS	0.771	**0.776***	~~0.890~~	~~0.876~~	**0.646***	~~0.895~~	~~0.902~~	**0.760***
XX_IPROI	0.710	**0.874***	~~0.843~~	**0.763***	~~0.882~~	~~0.953~~	**0.898***	~~0.930~~
XX_CSROI	0.702	**0.847***	**0.655***	~~0.879~~	~~0.927~~	**0.843***	~~0.931~~	~~0.923~~
XXXXTPSR	0.734	~~0.898~~	~~0.851~~	~~0.810~~	~~0.837~~	~~0.960~~	~~0.950~~	~~0.929~~

	XX_IPCS	XX_IPROI	XX_CSROI
XX_IPROI	~~0.893~~		
XX_CSROI	~~0.846~~	~~0.925~~	
XXXXTPSR	~~0.921~~	~~0.972~~	~~0.932~~

Source: MINITAB correlation report for response / independent variables and interaction terms.

Notes:

1) Variable pairs with ~~slashed~~ correlation coefficients are irrelevant, an interaction term will inherently be correlated with component variables.
2) Variable pairs with **bold** text are significantly correlated (r > c.v. $r_{.025,24} \approx 0.423$)and must be considered for model development.
3) Variable pairs with bold* marks are three variable interaction terms represented, for simplicity purposes, by the four variable interaction term XXXXTPSR.

Similar to the *Satisfaction* model, this matrix indicates that *all* pair-wise correlations are significant. The variables are not independent and interaction terms were added as candidates. The same interaction terms were added as for the first model: XXTSIP, XXCSIP, XXTSROI, XXTSCS, XXIPROI, XXCSROI, and XXXXTPSR. The model could demonstrate significant multicollinearity if more than one variable was added to the model. Therefore, the best subsets and step-wise regression methods were not

appropriate. Model building was again performed in a manual, one variable procedure. The complete model building summary is provided in Appendix E. The final MINITAB regression report is in Table 7.

Table 7

MODEL 2: FINAL REGRESSION ANALYSIS REPORT

```
Regression Analysis

The regression equation is
Value = 0.999 + 0.00842 XX_IPCS

24 cases used (4 cases contain missing values)

Predictor        Coef        Stdev    t-ratio        p
Constant       0.9985       0.5348       1.87    0.075
XX_IPCS      0.008421     0.001485       5.67    0.000 p<0.05 ∴ signif.

s = 0.7168      R-sq = 59.4%      R-sq(adj) = 57.5%

Analysis of Variance

SOURCE        DF          SS          MS         F        p
Regression     1      16.531      16.531     32.18    0.000
Error         22      11.303       0.514
Total         23      27.833

Unusual Observations
Obs.   XX_IPCS      Value       Fit  Stdev.Fit   Residual    St.Resid
 21        168      1.000     2.413      0.303     -1.413      -2.18R
 28        120      3.000     2.009      0.367      0.991       1.61 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

No evidence of lack of fit (P > 0.1)
Source MINITAB 10xtra linear regression output.
```

No significant additional independent or interaction terms could be added to the model. The general multiple regression again collapsed to a simple linear regression problem and was tested appropriately.

Figure 15 shows the fitted line plot for *Value* versus the *Increased Productivity / Customer Service* interaction term. The solid line marks the fitted regression equation for the sample data. The dotted-line marks the 95% confidence interval for the line. The 95% CI means that there is a 95% likelihood that the true population relation is oriented within the area marked by the dashed lines. The 95% prediction bands (PI) means that the true orientation of a line in future studies will lie within the wider constraints of those bands.

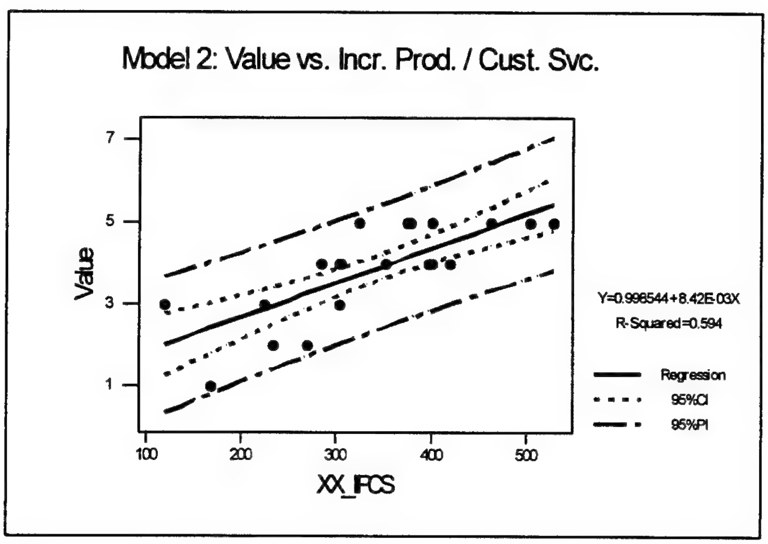

Figure 15

The residual plots shown in Appendix E demonstrate that the residuals are normally distributed. Figure 16 displays an annotated and exploded version of the normal probability plot:

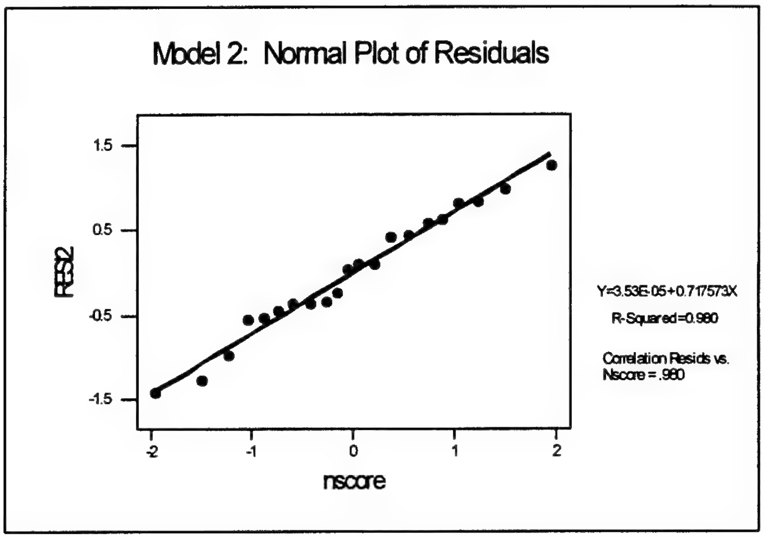

Figure 16

The correlation of the residuals and the normal score is 0.990, which is above the 0.959 critical value marking the rejection region. Therefore, it is concluded that the error terms are normally distributed.

The histogram demonstrates some skewness in the residuals but they still appear normally distributed. The chart shown in Figure 17 provides a more detailed picture of the standardized residual histogram.

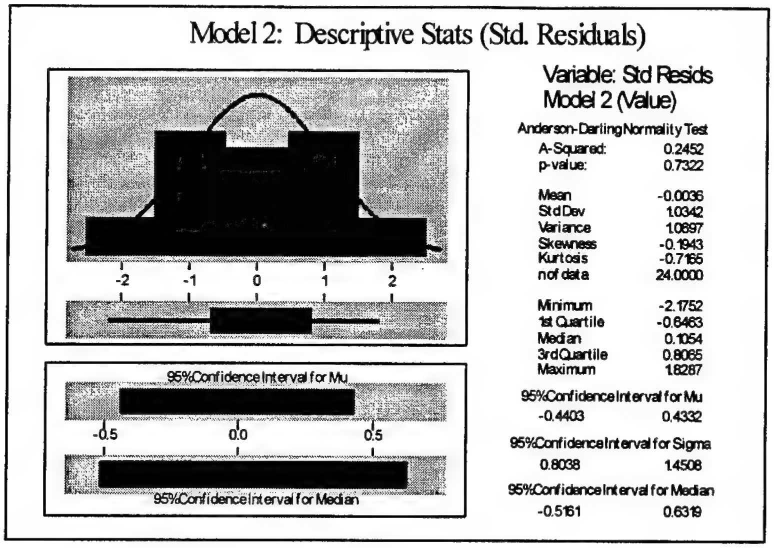

Figure 17

The box plot below the histogram demonstrates that the standardized residuals are effectively unskewed and are without significant outliers.

The one possible problem is the nearly linear patterns displayed in the residual vs. $\hat{Y}$ plot. This plot is provided in Figure 18.

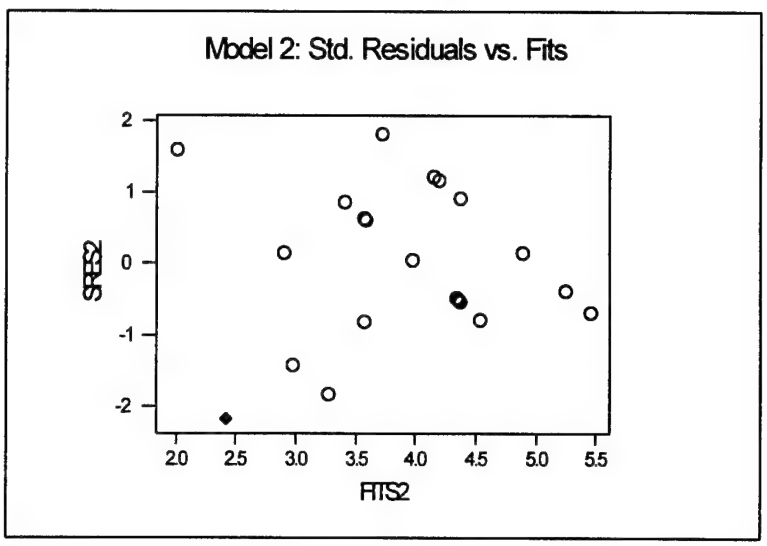

Figure 18

This plot suggests that the error terms may violate the non-independence assumption. The standardized residuals were further plotted against the interaction term and the two independent variables: *Increased Productivity* and *Customer Service*. These plots are shown in Figures 19-21.

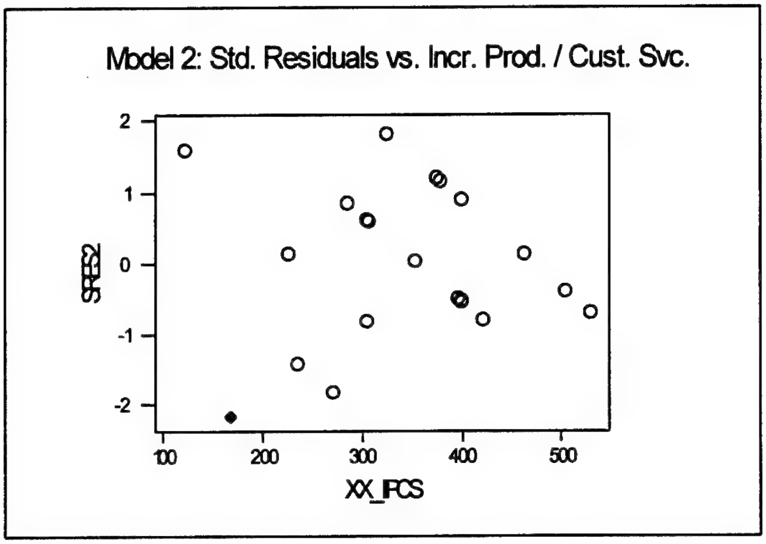

Figure 19

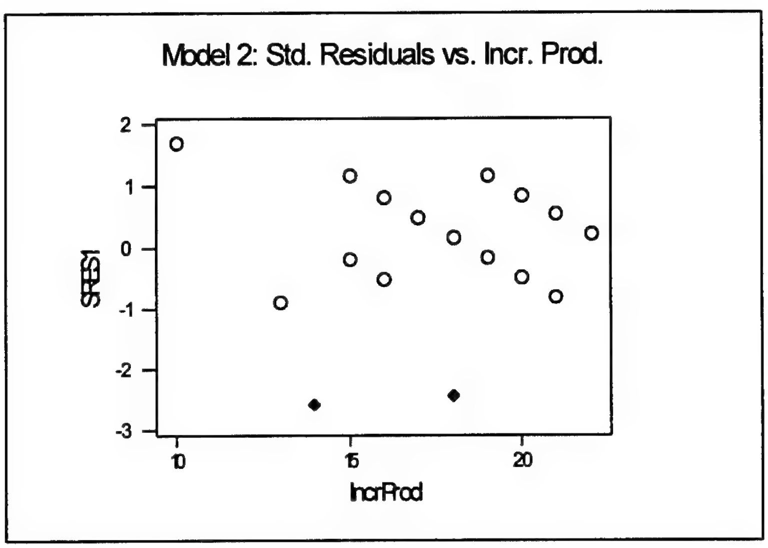

Figure 20

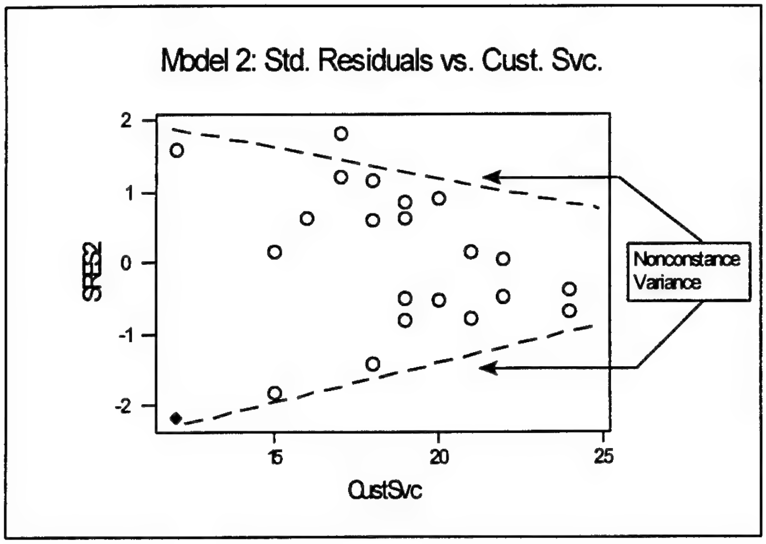

Figure 21

The residuals plotted against the interaction term as shown in Figure 19 demonstrate the same linear patterns as the residual vs. $\hat{Y}$ plot that were shown in the previous model. However, in this model, when the standardized residuals are plotted against *Improved Productivity,* the linear pattern is not apparent. Like the first model, the plot demonstrates even distribution about the mean and only one outlier point outside two standard deviations. The distribution appears to be random, as further indicated in the standard residual vs. $\hat{Y}$ plot. The apparent dependence on the independent variable may be due to the small range of the variable rather than a non-independence problem. Another possibility is a missing critical variable. However, just as was the case for the *Satisfaction* model, no independent variable or interaction term could be added to the model.

A significant linear relationship exists between the response variable *Value* and the independent variable *Increased Productivity*. The re-stated model is:

$$\textbf{\textit{Value}} = \mathbf{0.999 + 0.00842}\ \textbf{\textit{Incr. Productivity * Impr. Cust. Svc}}$$

The model meets all assumptions of the general linear model except, possibly, for the non-independence of residuals assumption. One should note the small value of the β_5 coefficient. Multicollinearity between *Improved Productivity* and *Customer Service* preclude using Bonferonni confidence intervals to ascertain if the coefficient is significantly different than zero. However, the p-value for each term as shown in Table 8 demonstrate significance of each coefficient.

The second model provides support for the second and third hypotheses as stated in section 4.2. Increased productivity and improved customer service positively affect value and increase the likelihood to purchase the technology.

4.3.1.3 Length of Use

The general model is adapted for the response variable *Length of Use* as follows:

$$[\textit{Length of Use}]_i = \beta_0 + \beta_1 \textit{TimeSav}_i + \beta_2 \textit{IncrProd}_i + \beta_3 \textit{ImprCustSvc}_i + \beta_4 \textit{IncrROI}_i + \varepsilon_i$$

where,

Length of Use$_i$ (Y_i) is the observed response in the i^{th} trial
TimeSav$_i$ (X_1), *IncrProd*$_i$ (X_2), *ImprCustSvc*$_i$ (X_3), *and IncrROI*$_i$ (X_4) are known constants, the level of the independent variables in the i^{th} trial
$\beta_0, \beta_1, \ldots, \beta_{p-1}$ are parameters
ε_i is an error term independent and normally distributed, $N(0, \sigma^2)$
$i = 1, \ldots, n$
$X_{i0} \equiv 1$

Once again, the correlation of candidate independent variables and the response variable *Length of Use* was determined. The critical value for Pearson's sample coefficient of correlation for $\alpha/2 = 0.025$ for sample size $n = 24$ ($r_{24,.025}$) was approximately 0.423 (Pearson and Hartley, 1966). The correlation matrix (extracted from MINITAB 10xtra output) is provided in Table 8:

Table 8

MODEL 3: CORRELATION MATRIX

Correlations (Pearson)

	LengUse	TimeSav	IncrProd	CustSvc	IncrROI	XX_TSIP	XX_TSCS	XX_TSROI
TimeSav	0.358							
IncrProd	0.404	**0.737**						
CustSvc	0.132	**0.675**	**0.582**					
IncrROI	0.079	**0.808**	**0.507**	**0.649**				
XX_TSIP	0.411	~~0.927~~	~~0.926~~	**0.666***	**0.755***			
XX_TSCS	0.282	~~0.932~~	**0.737***	~~0.885~~	**0.795***	~~0.891~~		
XX_TSROI	0.247	~~0.955~~	**0.697***	**0.702***	~~0.938~~	~~0.898~~	~~0.919~~	
XX_IPCS	0.305	**0.776***	~~0.890~~	~~0.876~~	**0.646***	~~0.895~~	~~0.902~~	**0.760***
XX_IPROI	0.192	**0.874***	~~0.843~~	**0.763***	~~0.882~~	~~0.953~~	**0.898***	~~0.930~~
XX_CSROI	0.225	**0.847***	**0.655**	~~0.879~~	~~0.927~~	**0.843***	~~0.931~~	~~0.923~~
XXXXTPSR	0.310	~~0.898~~	~~0.851~~	~~0.810~~	~~0.837~~	~~0.960~~	~~0.950~~	~~0.929~~

	XX_IPCS	XX_IPROI	XX_CSROI
XX_IPROI	~~0.893~~		
XX_CSROI	~~0.846~~	~~0.925~~	
XXXXTPSR	~~0.921~~	~~0.972~~	~~0.932~~

Source: MINITAB correlation report for response / independent variables and interaction terms.

Notes:

1) Variable pairs with ~~slashed~~ correlation coefficients are irrelevant, an interaction term will inherently be correlated with component variables.
2) Variable pairs with **bold** text are significantly correlated (r > c.v. $r_{.025,24} \approx 0.423$)and must be considered for model development.
3) Variable pairs with **bold*** marks are three variable interaction terms represented, for simplicity purposes, by the four variable interaction term XXXXTPSR.

The correlation matrix indicates *all* pair-wise correlations are significant. The variables are not independent and interaction terms were added as candidates. The same interaction terms were added as for the first model: XXTSIP, XXCSIP, XXTSROI,

XXTSCS, XXIPROI, XXCSROI, and XXXXTPSR. The model could demonstrate significant multicollinearity if more than one variable was added to the model. Therefore, the best subsets and step-wise regression methods were not appropriate. Model building was again performed in a manual, one variable procedure. The complete model building summary is provided in Appendix F. The final MINITAB regression report is provided in Table 9.

Table 9

MODEL 3: FINAL REGRESSION ANALYSIS REPORT

```
Regression Analysis

The regression equation is
LengUse = 0.280 + 0.00482 XX_TSIP

24 cases used 4 cases contain missing values

Predictor        Coef       Stdev    t-ratio       p
Constant       0.2805      0.8332       0.34   0.740
XX_TSIP      0.004825    0.002282       2.11   0.046

s = 1.244      R-sq = 16.9%     R-sq(adj) = 13.1%

Analysis of Variance

SOURCE       DF         SS          MS        F        p
Regression    1      6.918       6.918     4.47    0.046
Error        22     34.041       1.547
Total        23     40.958

Unusual Observations
Obs.  XX_TSIP    LengUse        Fit   Stdev.Fit    Residual     St.Resid
  1       462      5.000      2.510       0.364       2.490        2.09R
  2       420      5.000      2.307       0.303       2.693        2.23R
  8       440      5.000      2.403       0.330       2.597        2.16R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)
Source MINITAB 10xtra linear regression output.
```

No significant additional independent or interaction terms could be added to the model. The general multiple regression again collapsed to a simple linear regression problem and was tested appropriately. Figure 22 shows the fitted line plot for *Length of Use* versus the *Increased Productivity / Time Saving* interaction term. The solid line marks the fitted regression equation for the sample data. The dotted-line marks the 95% confidence interval for the line. The 95% CI means that there is a 95% likelihood that the true population relation is oriented within the area marked by the dashed lines. The 95% prediction bands (PI) means that the true orientation of a line in future studies will lie within the wider constraints of those bands.

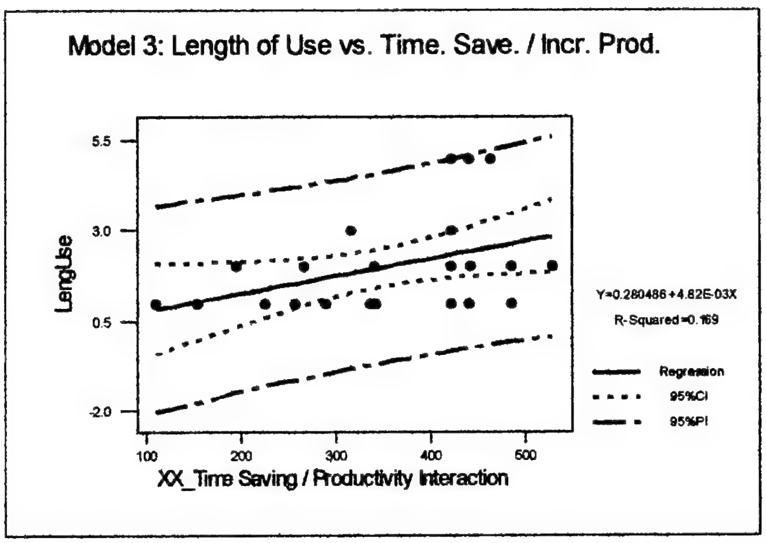

Figure 22

The residual plots shown in Appendix F demonstrate that the residuals are normally distributed. Figure 23 displays an annotated and exploded version of the normal probability plot.

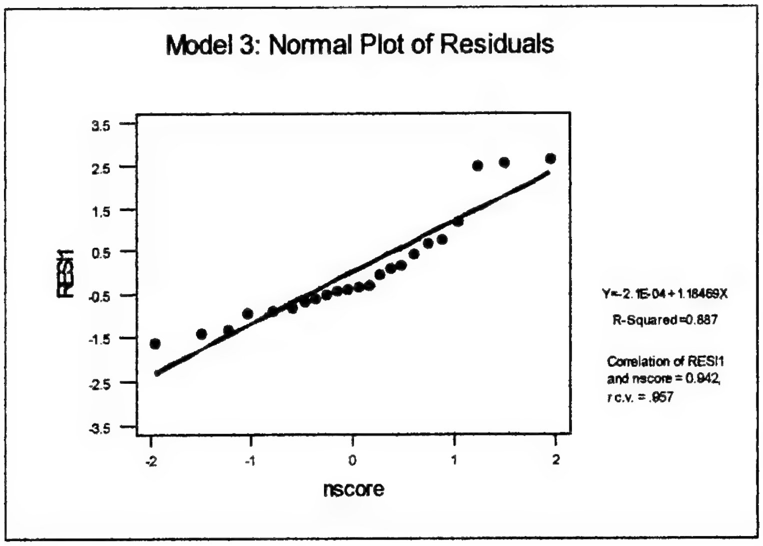

Figure 23

The coefficient of correlation between the residuals and the nscore quantile plot is within the rejection region as shown in Figure 24 (Neter, 1990).

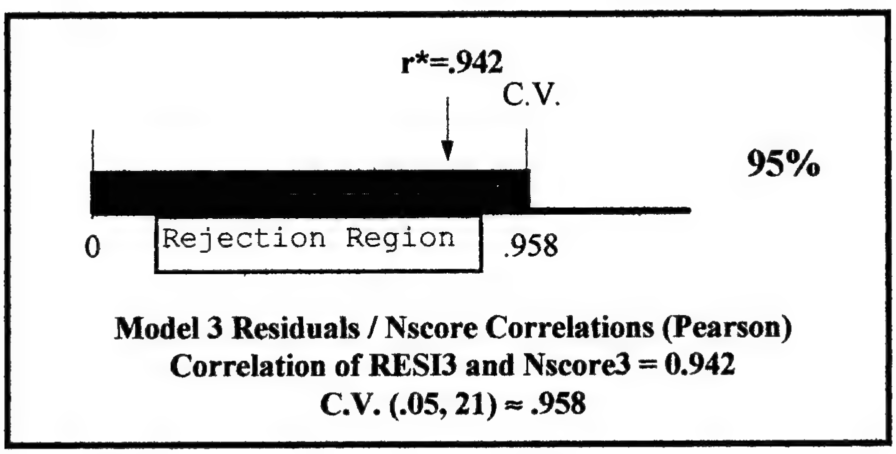

Figure 24

It is therefore concluded that there are significant departures of normality for the residuals in this model.

The histogram of standardized residuals demonstrates considerable deviation from normality. The chart shown in Figure 25 provides a more detailed picture of the standardized residual histogram.

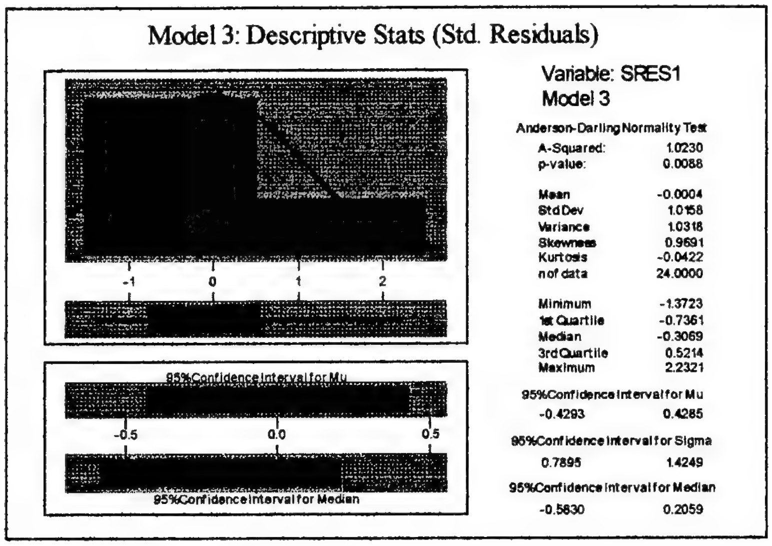

Figure 25

The misalignment of the mean and median CI boxes as well and the unbalanced box plot further demonstrates deviation from normality. Finally, the low p-value shown in the Anderson-Darling Normality test conclusively indicate the residuals are not normally distributed in this model.

The residual vs. $\hat{Y}$ chart is provided in Figure 26. The linear arrangements evident in previous models now are exaggerated sufficiently to appear as non-constant variance or fanning, and problem that requires transformations to correct.

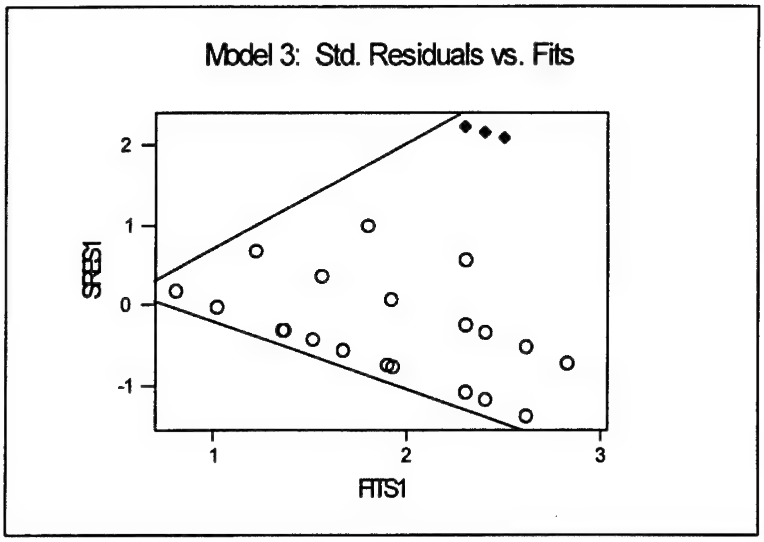

Figure 26

This plot suggests that the error terms may violate the non-independence assumption. The standardized residuals were further plotted against the interaction term and the two independent variables: *Increased Productivity* and *Customer Service*. These plots are shown in Figures 27 - 29.

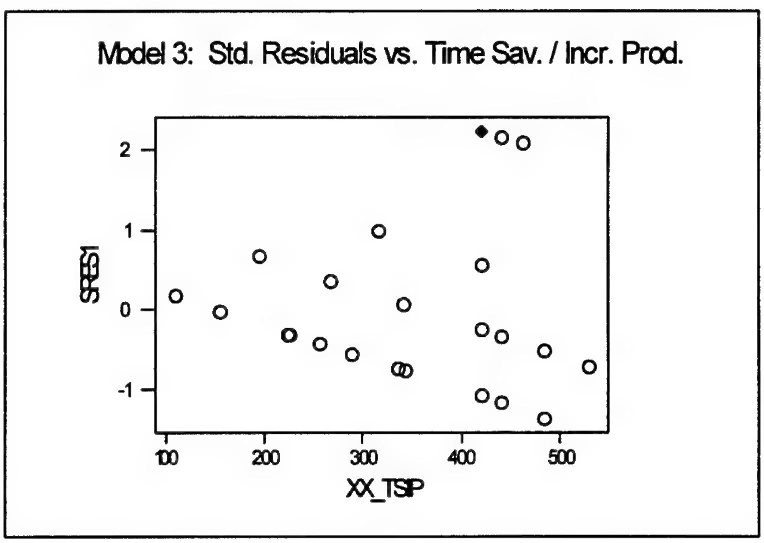

Figure 27

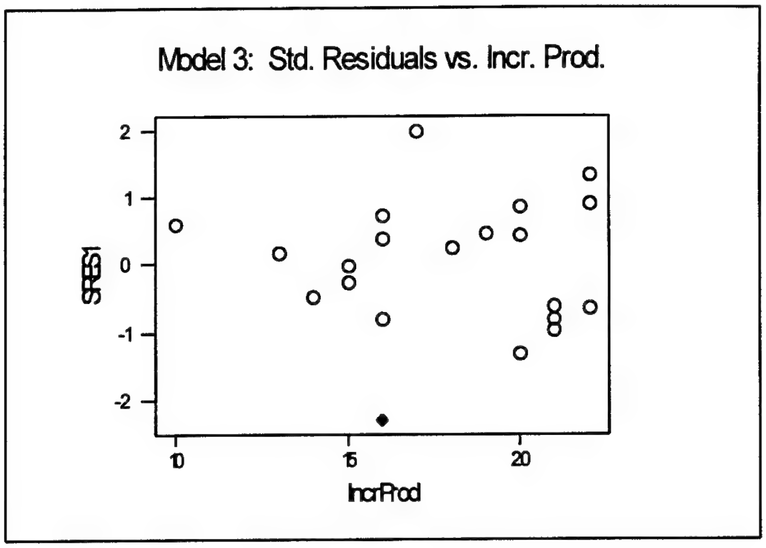

Figure 28

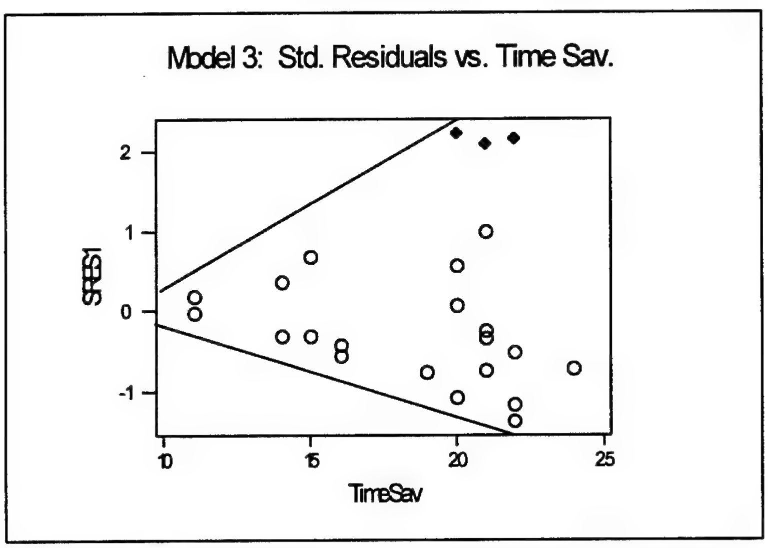

Figure 29

The residuals plotted against the interaction term as shown in Figure 27 demonstrate the same linear patterns as the residual vs. $\hat{Y}$ plot and that shown in the previous model. However, in this model, when the standardized residuals are plotted against *Improved*

Productivity, the linear pattern is not apparent. Like the first model, the plot demonstrates even distribution about the mean and only one outlier point outside two standard deviations. The distribution does appear to be uniform as also indicated in the standard residual vs. $\hat{Y}$ plot. The apparent dependence on the independent variable may be due to the small range of the variable rather than a non-independence problem. Another possibility is a missing critical variable. However, just as was the case for the *Satisfaction* model, no independent variable or interaction term could be added to the model.

While a significant linear relation exists between *Length of Use* and the independent variable *Increased Productivity / Customer Service* interaction term, the model violations mitigate the utility of the model. The re-stated model is:

$$\textit{Length of Use} = 0.280 + 0.00482\ \textit{Incr. Productivity} * \textit{Time Savings}$$

The model violates all assumptions of the general linear model. Consequently it does not support any of the four hypotheses.

4.3.1.4 Number of Vehicles (Percentage of Fleet)

The general model is adapted for the response variable *Number of Vehicles* as follows:

$$[\textit{No. Veh.}]_i = \beta_0 + \beta_1 \textit{TimeSav}_i + \beta_2 \textit{IncrProd}_i + \beta_3 \textit{ImprCustSvc}_i + \beta_4 \textit{IncrROI}_i + \varepsilon_i$$

where,

No. Veh.$_i$ (Yi) is the observed response in the i^{th} trial

TimeSav$_i$ (X_1), *IncrProd*$_i$ (X_2), *ImprCustSvc*$_i$ (X_3), *and IncrROI*$_i$ (X_4) are known constants, the level of the independent variables in the i^{th} trial

$\beta_0, \beta_1, \ldots, \beta_{p-1}$ are parameters

ε_i is an error term independent and normally distributed, $N(0, \sigma^2)$

$i = 1, \ldots, n$

$X_{i0} \equiv 1$

Once again, the correlation of candidate independent variables and the response variable *No. Veh.* was determined. The critical value for Pearson's sample coefficient of correlation for $\alpha/2 = 0.025$ for sample size $n = 24$ ($r_{24,.025}$) was approximately 0.423 (Pearson and Hartley, 1966). The correlation matrix (extracted from MINITAB 10xtra output) is provided in Table 10.

Table 10

MODEL 4: CORRELATION MATRIX

Correlations (Pearson)

	No_Veh	TimeSav	IncrProd	CustSvc	IncrROI	XX_TSIP	XX_TSCS	XX_TSROI
TimeSav	0.379							
IncrProd	0.243	**0.737**						
CustSvc	0.362	**0.675**	**0.582**					
IncrROI	0.088	**0.808**	**0.507**	**0.649**				
XX_TSIP	0.333	~~0.927~~	~~0.926~~	**0.666***	**0.755***			
XX_TSCS	0.421	~~0.932~~	**0.737***	~~0.885~~	**0.795***	~~0.891~~		
XX_TSROI	0.257	~~0.955~~	**0.697***	**0.702***	~~0.938~~	~~0.898~~	~~0.919~~	
XX_IPCS	0.346	**0.776***	~~0.890~~	~~0.876~~	**0.646***	~~0.895~~	~~0.902~~	**0.760**
XX_IPROI	0.146	**0.874***	~~0.843~~	**0.763***	~~0.882~~	~~0.953~~	**0.898***	~~0.930~~
XX_CSROI	0.268	**0.847***	**0.655***	~~0.879~~	~~0.927~~	**0.843***	~~0.931~~	~~0.923~~
XXXXTPSR	0.308	~~0.898~~	~~0.851~~	~~0.810~~	~~0.837~~	~~0.960~~	~~0.950~~	~~0.929~~

	XX_IPCS	XX_IPROI	XX_CSROI
XX_IPROI	~~0.893~~		
XX_CSROI	~~0.846~~	~~0.925~~	
XXXXTPSR	~~0.921~~	~~0.972~~	~~0.93~~

Source: MINITAB correlation report for response / independent variables and interaction terms.

Notes:

1) Variable pairs with ~~slashed~~ correlation coefficients are irrelevant, an interaction term will inherently be correlated with component variables.
2) Variable pairs with **bold** text are significantly correlated (r > c.v. $r_{.025,24} \approx 0.423$) and must be considered for model development.
3) Variable pairs with **bold*** marks are three variable interaction terms represented, for simplicity purposes, by the four variable interaction term XXXXTPSR.

The correlation matrix indicates *all* pair-wise correlations are significant. The variables are not independent and interaction terms were added as candidates. The same interaction terms were added as for the first model: XXTSIP, XXCSIP, XXTSROI, XXTSCS, XXIPROI, XXCSROI, and XXXXTPSR. The model demonstrated significant multicollinearity. Therefore, the best subsets and step-wise regression methods were not appropriate. Model building was again performed in a manual, one variable procedure. The complete model building summary is provided in Appendix G. The final MINITAB regression report is provided in Table 11.

Table 11

MODEL 4: FINAL REGRESSION REPORT

Final Regression Analysis

The regression equation is
No_Veh = 5.99 + 0.0221 XX_TSCS - 0.382 IncrROI - 0.312 IncrProd

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	5.989	2.024	2.96	0.009	
XX_TSCS	0.022071	0.005433	4.06	0.001	4.9
IncrROI	-0.3816	0.1459	-2.62	0.018	2.8
IncrProd	-0.3116	0.1365	-2.28	**0.036**	2.6

s = 1.270 R-sq = 50.4% **R-sq(adj) = 41.6%**

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	3	27.837	9.279	5.76	0.007
Error	17	27.401	1.612		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_TSCS	1	10.917
IncrROI	1	8.526
IncrProd	1	8.394

Proper Model Build

Unusual Observations

Obs.	XX_TSCS	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
11	270	5.000	4.845	0.969	0.155	0.19 X
12	399	1.000	3.704	0.484	-2.704	-2.30R
13	360	5.000	2.532	0.317	2.468	2.01R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.
No evidence of lack of fit (P > 0.1)

Source: MINITAB linear regression output

The fourth model was the only one having more than a single variable significantly enter the model. In this case the VIF was used to provide diagnostics for excessive

collinearity. The extra sum of squares method was used to ensure proper model building. The formal hypothesis test for this relation is summarized below. Bonferroni Joint Confidence Intervals could not be performed to test each coefficient due the multicollinearity in the model.

Figures 30-32 show the fitted line plots for *Length of Use* versus the independent terms. The solid line marks the fitted regression equation for the sample data. The dotted-line marks the 95% confidence interval for the line. The 95% CI means that there is a 95% likelihood that the true population relation is oriented within the area marked by the dashed lines. The 95% prediction bands (PI) means that the true orientation of a line in future studies will lie within the wider constraints of those bands.

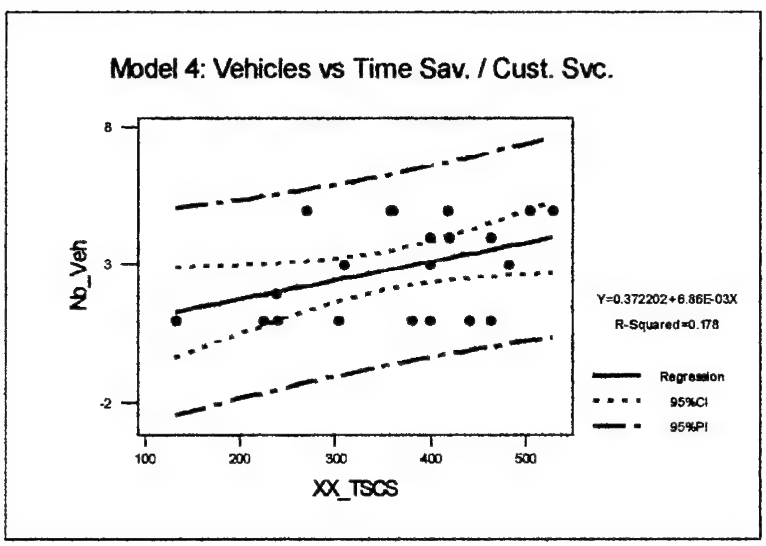

Figure 30

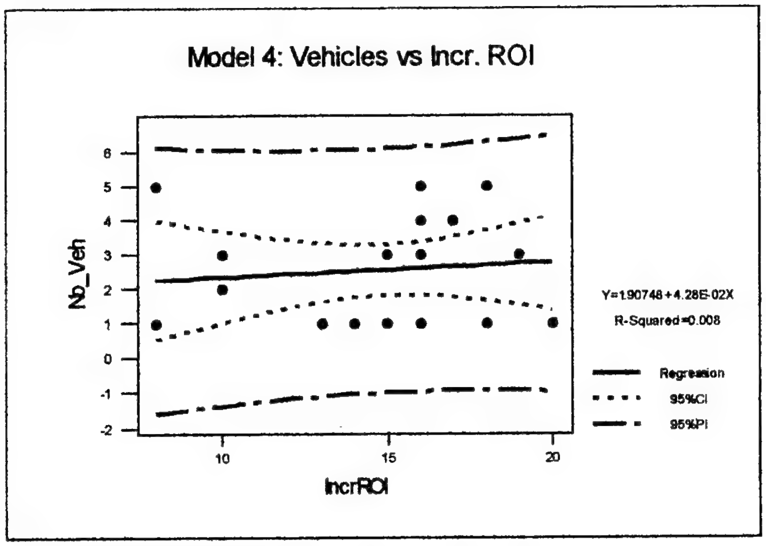

Figure 31

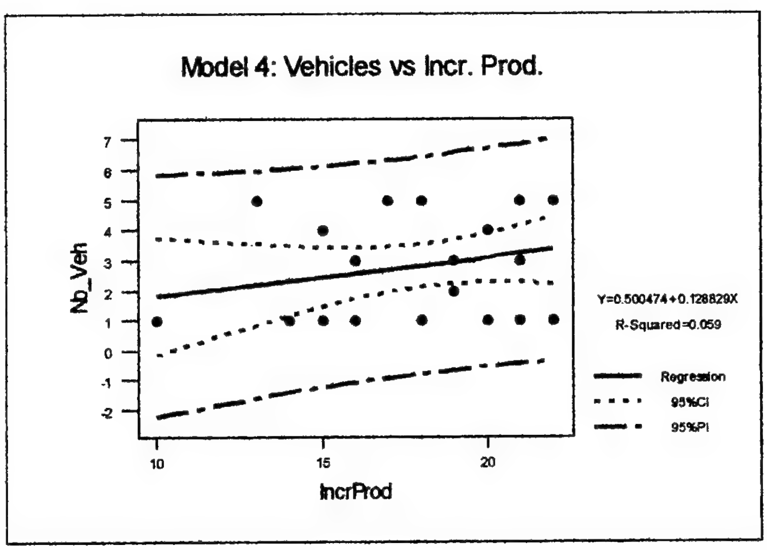

Figure 32

The residual plots shown in Appendix F demonstrate that the residuals are normally distributed. Figure 33 displays an annotated version of the normal probability plot.

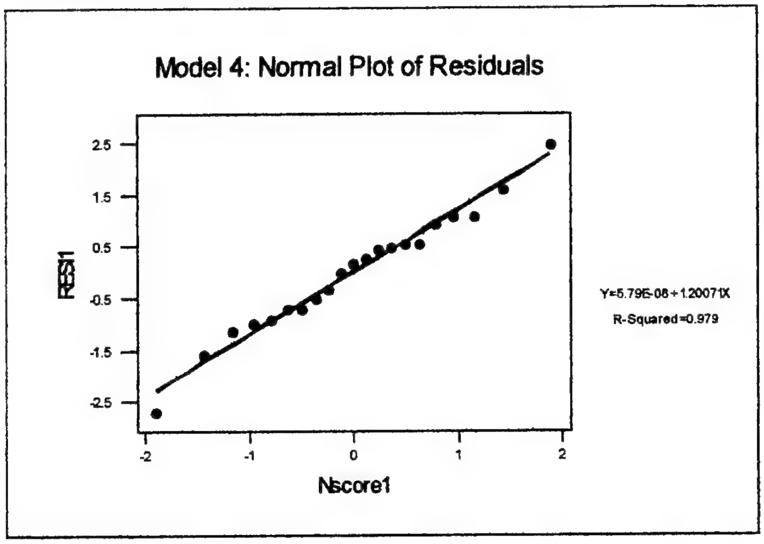

Figure 33

The coefficient of correlation between the residuals and the nscore quantile plot is within the rejection region as shown in Figure 34 (Neter, 1990).

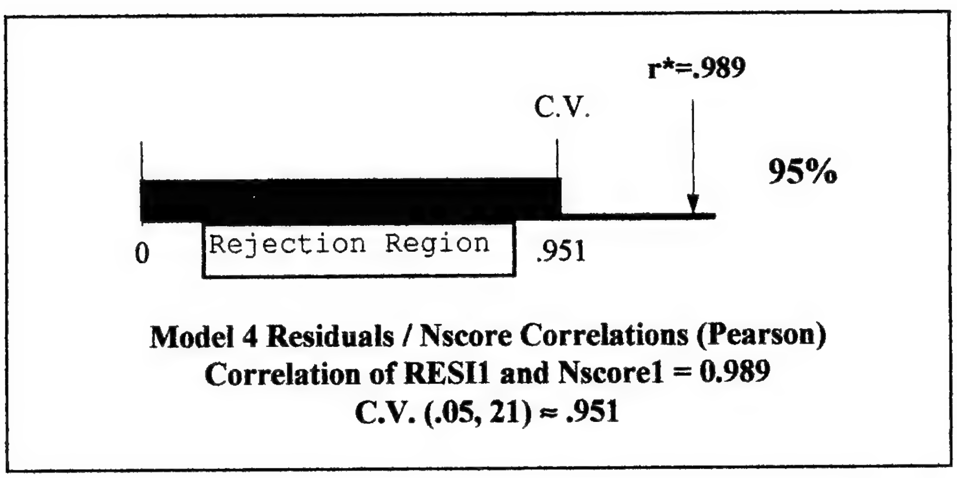

Figure 34

The correlation of the residuals with the normal plot is outside the rejection region. Therefore, it is concluded that the residuals are normally distributed.

The histogram of standardized residuals demonstrate the strongest similarity to a normal distribution of all models. The chart shown in Figure 35 provides a detailed picture of the standardized residual histogram. The box chart does indicate the residuals are negatively skewed about the mean, but do not show any outliers.

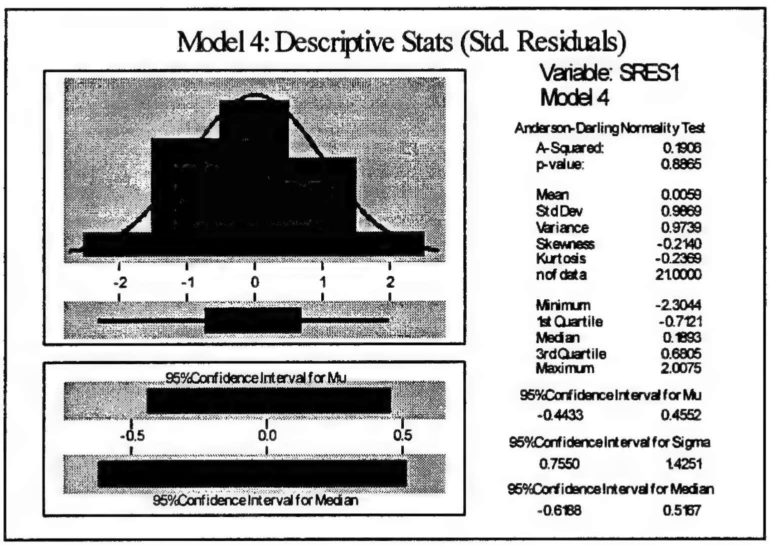

Figure 35

Finally, the high p-value shown in the Anderson-Darling Normality test supports the determination that the residuals are normally distributed in this model.

The residual vs. $\hat{Y}$ chart is provided in Figure 36. The linear arrangements evident in previous models now are exaggerated sufficiently to appear as non-constant variance or fanning, and problem that requires transformations to correct.

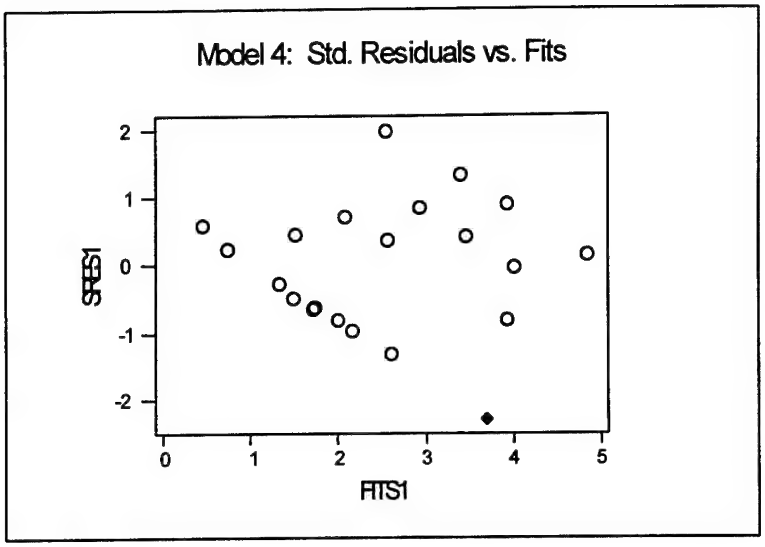

Figure 36

This plot suggests that the error terms may violate the non-independence assumption. The standardized residuals were further plotted against the interaction term and the two independent variables: *Increased Productivity* and *Customer Service*. These plots are shown below in Figures 37 - 39.

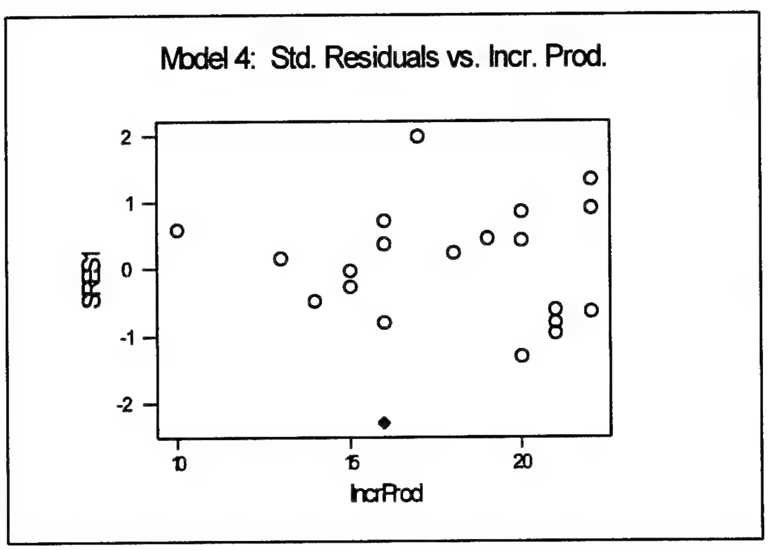

Figure 37

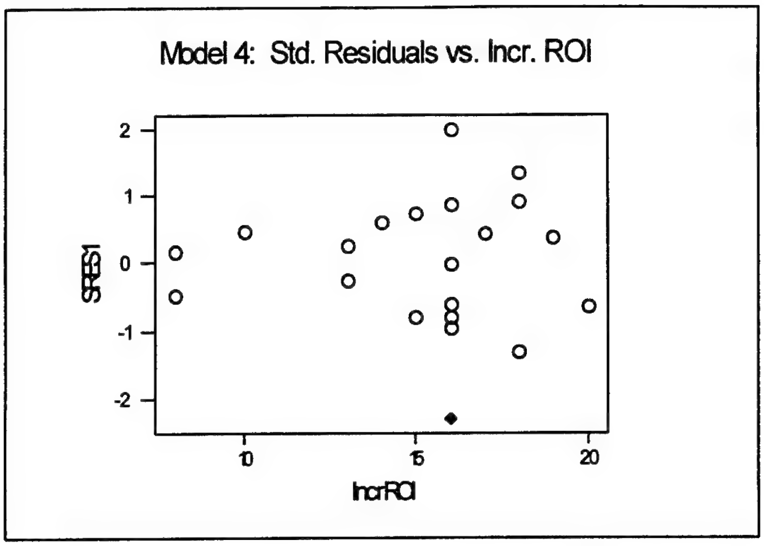

Figure 38

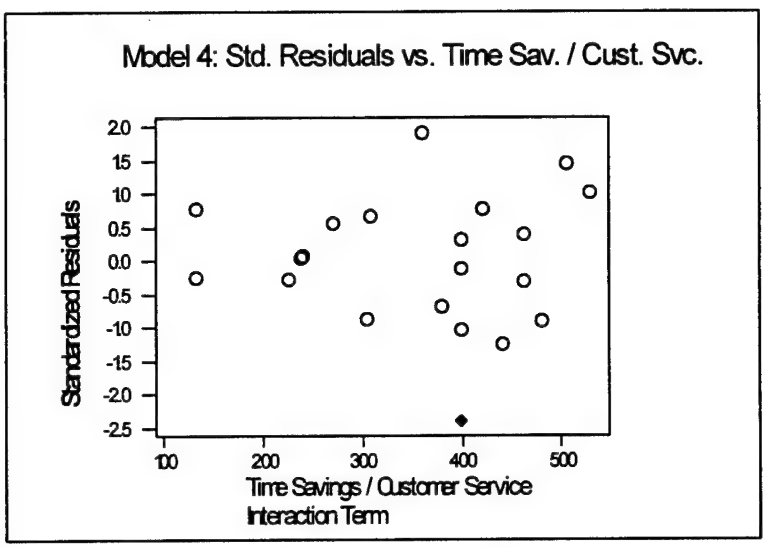

Figure 39

The residual plots all demonstrate a possible problem with non-constant variance, fanning or heteroscedasticity. However, the corrective procedure necessary to adjust the model was not performed due to the multicollinearity problem. Transformations on one variable would affect the other two independent terms leading to an unsatisfactory if not insolvable result.

Figures 40 - 42 were pair-wise plots of the independent variables. These plots were done to graphically demonstrate the degree of linear correlation between each variable pair. Correlation is evident when ever a linear pattern is demonstrated. The stronger the correlation between each variable, the closer the pattern will resemble in linear plot. Ideally, the independent variable should not be correlated and no pattern should be evident.

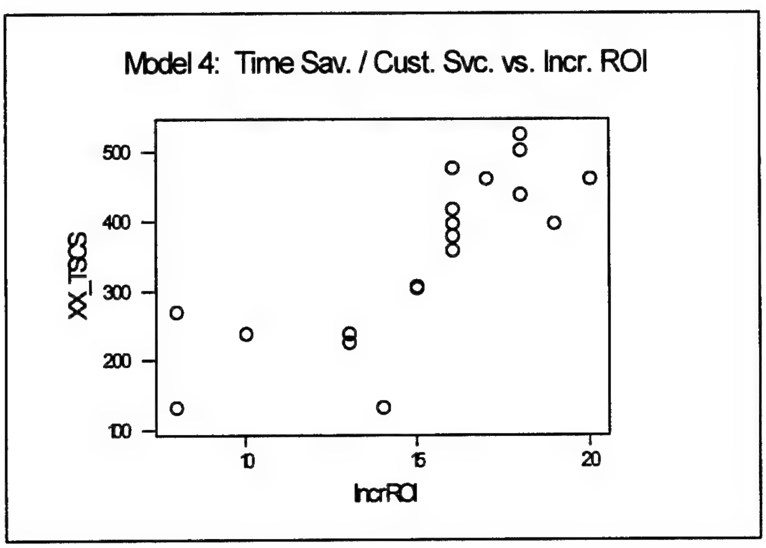

Figure 40

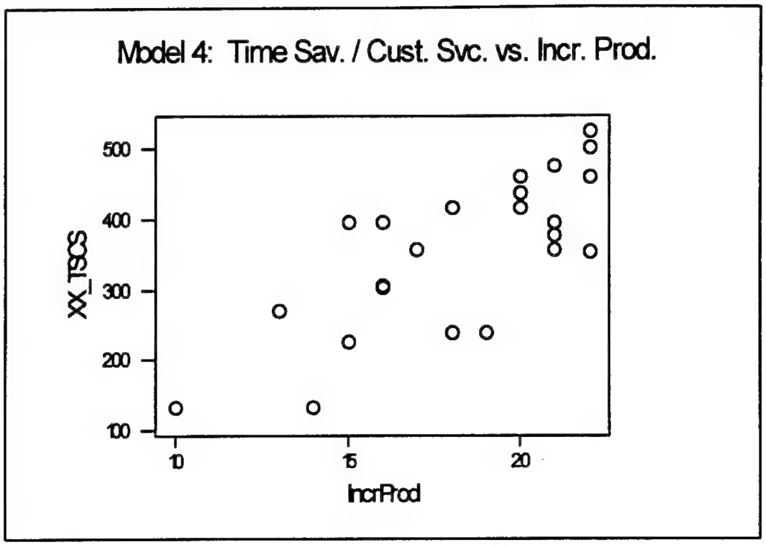

Figure 41

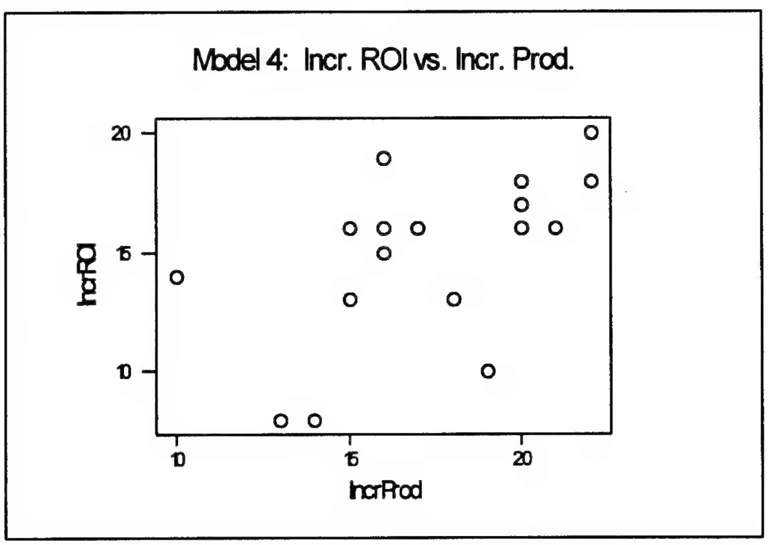

Figure 42

The residuals plotted against the interaction term as shown in Figure 39 demonstrate the same linear patterns as the residual vs. $\hat{Y}$ plot and that shown in the previous model. However, in this model, when the standardized residuals are plotted against *Improved Productivity,* the linear pattern is not apparent. Like the first model, the plot demonstrates even distribution about the mean and only one outlier point outside two standard deviations. The distribution does appear to be random as also indicated in the standard residual vs. $\hat{Y}$ plot. The apparent dependence on the independent variable may be due to the small range of the variable rather than a non-independence problem. Another possibility is a missing critical variable. However, just as was the case for the *Satisfaction* model, no independent variable or interaction term could be added to the model.

While a significant linear relation exists between *No. Veh.* and the independent variable *Increased Productivity / Customer Service* interaction term, the model violations mitigate the utility of the model. The re-stated model is:

Percentage of Vehicles = 5.99 + 0.0221 Time Savings / Customer Service

- 0.382 Increased ROI - 0.312 Increased Productivity

The negative coefficients in the final two terms are counter intuitive. However, since multicollinearity is present and effects all coefficients, this result is appropriate. The linear relationship is significant, as are the coefficients for the various terms. The model could not be built at a 95% confidence level. The terms shown above were manually

built with a relaxed 90% confidence level. The first variable, the Time Savings / Customer Service interaction term, entered with a P-value of 0.054 (See Appendix G). All other terms entered and were significant with P-values less than 0.005. In summary the coefficients as a whole are significant at a 94% confidence level. The lack-of-fit test is significant at a 95% confidence level.

While there are some problems with multicollinearity, which influences the coefficients for the three terms, the model is significant. The model supports the first and third hypotheses, time savings and improved customer service, and positively effects the likelihood to purchase satellite-based tracking technology.

4.3.2 Statistical Summary

Given the four hypotheses stated previously, wherein all identified benefits were postulated to have a positive influence on a firm's likelihood to purchase satellite-based technology, the results of the survey and statistical analysis of the data indicate otherwise. Specifically, problems with multicollinearity effects in variable coefficients prevent definitive analysis of positive or negative influence in the four models for *Satisfaction*, *Value*, *Length of Use* and *Percentage of Fleet Equipped*. However, the strongest models were Satisfaction and Value. These two models reflected the highest adjusted coefficients of determination (63.9 and 57.5 respectively), and demonstrated a significant, positive relationship between the variables *Increased Productivity* and *Improved Customer Service*. The third model, *Length of Use*, suffers from very low coefficient of

determination and assumption errors, and will not be used for any inferences. The fourth model also suffers from assumption difficulties but has a significant linear relationship. The fourth model will not be used due to the various assumption errors and due to the low adjusted coefficient of multiple determination (R^2).

The four models and their coefficients are summarized below.

Model 1:

$$[Satisfaction]_i = \beta_0 + \beta_2 IncrProd_i)$$
$$\beta_0 = -0.312 \quad \beta_2 = \mathbf{+0.231}$$

Model 2:

$$[Value]_i = \beta_0 + \beta_5 (IncrProd_i * ImprCustSvc_i)$$
$$\beta_0 = +0.999 \quad \beta_5 = \mathbf{+0.00842}$$

Model 3:

$$[LengthUse]_i = \beta_0 + \beta_6 (IncrProd_i * TimeSav_i)$$
$$\beta_0 = +0.280 \quad \beta_6 = \mathbf{+0.00482}$$

Model 4:

$$[No.\ Veh.]_i = \beta_0 + \beta_7 (TimeSav_i * ImprCustSvc_i) + \beta_4 IncrROIi + \beta_2 IncrProdi$$
$$\beta_0 = +5.99 \quad \beta_7 = \mathbf{+0.0221} \quad \beta_4 = \mathbf{-0.382} \quad \beta_2 = \mathbf{-0.312}$$

Table 12 provides a summary of the three tests performed on each model. The first test was a global lack of fit test which determined if a significant linear relationship existed between the various independent variables and the response variables. The second test determined if the coefficients (β_k) were significantly different than zero. The third and final test was a test of model assumptions using residual plots and normal probability plots as discussed previously.

Table 12

FORMAL MODEL TESTS AND DIAGNOSTICS

Model	Adj. r^2	Global Lack of Fit Test	Test of β_k Coefficients	Check of Assumptions
1 *Satisf*	63.9 %	F^* = 43.47 $F_{C.V.}$ = 4.28 **L.R. is significant** **(P-value = 0.000)**	β_2 t^* = 6.59 $t_{C.V.}$ = 2.069 **β_k is significant** **(P-value = 0.000)**	Possible non-independence of ε_i terms
2 *Value*	57.5%	F^* = 32.18 $F_{C.V.}$ = 4.31 **L.R. is significant** **(P-value = 0.000)**	β_5 t^* = 5.67 $t_{C.V.}$ = 2.074 **β_k is significant** **(P-value = 0.000)**	Possible non-independence of ε_i terms
3 *LengthUse*	13.1 %	F^* = 4.47 $F_{C.V.}$ = 4.31 **L.R. is significant** **(P-value = 0.046)**	β_6 t^* = 2.11 $t_{C.V.}$ = 2.074 **β_k is significant** **(P-value = 0.046)**	Possible non-independence of ε_i terms Non-normal distribution of ε_i
4 *No.Veh.*	41.6 %	F^* = 5.76 $F_{C.V.}$ = 3.21 **L.R. is significant** **(P-value = 0.007)**	β_7 t^* = 2.18 (P = 0.040) β_4 t^* = -2.07 (P = 0.053) β_2 t^* = -2.28 (P = 0.036) $t_{C.V.}$ = 1.717/1.734/1.740 (α = 0.10) **β_k are significant @ 90%**	Possible non-independence of error terms Heteroscedasticity

NOTES:
Unless stated otherwise tests were conducted for $\alpha = 0.05$, a 95% confidence level
L.R. = linear relation

Table 12 shows that all four models suffer from possible dependent error terms. A common interpretation of this problem is that a signficant variable is missing from the model. Model 3 (Length of Use) had a very low coefficient of determination indicating the model fails to explain a majority of the total variation in the sample data. Model 4 has a comparable problem. Additionally, the fourth model suffers from non-constant variance in two terms as shown previously. This heteroscedasticity problem was not corrected with transformations due to the low coefficient of multiple determination and

multicollinearity problems. The transformations would complicate interpretation and the model was not strong enough to support any hypotheses.

On the basis of the first two models, data supports the second and third hypotheses; however, due to the multicollinearity, neither the first nor the fourth hypotheses can be accepted or rejected. All four models had a problem with variable independence, suggesting that perhaps a major variable was missing from the model. Since all variables were examined, any missing variables were outside the scope of the survey. Possible missing variables could include: cost of the technology, size of the firm, or type of services provided by the firm, i.e., less-than-truckload (LTL), truckload (TL), regional, or national.

Perhaps the most revealing of the findings of the survey is that a large number of trucking firms view satellite-based tracking systems as too costly, and in most cases this is strictly an assumption, since respondents state that they have not "looked into" the technology. Additionally, a large number of the firms view the technology as beneficial to only those companies that cover large geographical areas, such as national carriers. For example, one respondent stated that due to the nature of his firm's business, he did not view the technology as being beneficial. Another claimed that the limited scope of his operating area did not necessitate such advanced technology. Both of these respondents identified themselves as LTL carriers. On the other hand, proving that some in the commercial trucking industry truly have little understanding of satellite-based technology, one truckload (TL) firm stated that only those in the less-than-truckload

(LTL) business could justify use of the technology. Four respondents reported that their firms are currently studying the technology, and two firms mentioned that they are waiting for the costs of the technology to drop.

The majority of non-user respondents reported that they currently use pager/beeper systems to communicate with their drivers; cellular communications was the next most popular method used. More often than not, non-user respondents reported using more than one means of communicating with their drivers. Again, it appears the non-user respondents are unaware that the price of satellite-based technology has drastically dropped, and that in many cases the technology is actually cheaper to use than cellular technology.

Chapter 5

CONCLUSION

5.1. Findings

5.1.1 Commercial Implications

The primary purpose of this research was to assess the benefits of satellite-based tracking technology in the commercial trucking industry and to further predict or project how the U.S. Army can use this technology to improve readiness and reduce costs. Four specific benefits of the technology were identified and examined: time savings, increased productivity, improved customer service, and increased return on investment (ROI). A survey sent to members of the American Association of Motor Carriers provided data on each of these benefits.

A number of non-user respondents stated that they felt the technology had little or no benefit for LTL firms. However, a thorough literature review revealed that even small, regional companies which operate a fleet are able to derive *some* benefit from the use of satellite-based technology. This lack of knowledge on the part of such a large number of carrier firms suggests that the vendors of the technology have failed in their marketing of the system. Additionally, the literature review revealed that the costs for the technology have dropped significantly over the last several years. Since an overwhelming number of non-user respondents commented that the technology was too expensive to justify its use, this further supports the idea that vendors have failed in the

advertising/marketing of their hardware. The refined marketing plan should emphasize not only reduced cost reductions in the hardware and software, but most importantly the benefits to small and mid-size users. The marginal benefits must exceed the marginal costs or commercial firms will not generate additional profit. In the military application the costs are constrained by congressional action through the budget process. The key to acquiring and applying the technology in new areas and organizations is on the benefit side. Military logistic users also must market the benefits of the technology to the end-user to obtain sufficient priority in the material acquisition process.

5.1.2 Military Implications

Statistical analysis of the collected data revealed that increased productivity has the greatest impact or influence on a firm's decision to purchase satellite-based technology. Improved customer service has an impact as well. Comparable military measures to increased productivity include "increased readiness," "improved responsiveness", "increased force effectiveness", and "increased combat capability." Improved customer service, when related to military operations, can equate to "decreased attrition", "increased synchronization", and "improved economy of force."

Today's Army no longer faces direct conflict with the world's superpowers. Instead, the Army participates to a greater extent in humanitarian missions and low intensity conflicts. As a result, smaller forces are dispatched to a greater number of locations, and because of this, Army logistics needs to be more flexible, and more agile.

The increased productivity provided by satellite-based technology will allow the Army logistician to be more efficient, and thus help to increase the overall effectiveness of the fighting force. The technology will allow Army transporters to operate with a greater knowledge of the combat fighter's needs. Re-supplies can be better anticipated, and the re-routing of supplies more precisely directed. Just as in the commercial sector, where satellite-based technology helps to improve the information management systems, the technology similarly strengthens the Army's command and control elements within the transportation arena. Use of the technology will alleviate problems commonly associated with rendezvous supply transactions and improve the operations at transfer points by providing more precise scheduling of these activities.

In addition to increased productivity, the use of satellite-based tracking technology allows for improved customer service, an important aspect of Army logistics, particularly when the customer is the combat fighter. The technology, when applied to the Army's distribution system, can help to decrease attrition on the battlefield by more precisely delivering much needed supplies to the right place, at the right time. Additionally, the use of satellite-based technology will permit Army transporters to react more swiftly to changes on the battlefield. That is, as the combat units face engagement, the logistics officer at the command and control center can more quickly and more efficiently direct his drivers with supplies.

5.2. Recommendations

The Army can ill afford to equip each and every one of its vehicles with satellite-based tracking equipment; it must, therefore, identify and prioritize its key logistical assets. For example, those mobile assets used to deliver ammunition and fuel to the combat fighters should be among the first to be equipped with satellite-based tracking equipment. Furthermore, rather than be considered a *force sustainer*, Army logistics needs to be considered a **force multiplier.**

Doctrinally, the Army should consider creating a tactical logistics cell in the forward command post where most other support cells are located (operations, intelligence, air defense, fire support, air support, and combat engineering) in order to better monitor mobile assets. Currently, logisticians do not have any means of influencing the tactical battlefield. Unlike the artillery commander who can direct support artillery and rocket fire against real-time enemy formations, the logistician must wait for periodic logistic or operational reports that only circumspectly address logistical problems. Detailed logistical reports are only generated every six to twelve hours and are not received by the logistical planning cell for three or four hours after they have been generated. The logisticians are always using and planning their support with obsolete information. However, if the logistician had real-time information on the location of, and communications links to critical assets like fuel and ammunition, the staff officer could expedite the movement of that asset to the exact place and time on the battlefield where it is needed. GPS and improved voice and digital communications technology have the

potential to dramatically alter the way logisticians perform their duties and the way the U.S. Army fights its wars. It is imperative that the logistics officer becomes an active, **real-time** member of the combat team, rather than a mere planner or "fire-fighter."

5.3. Future Research

One of the fundamental areas not addressed is the manner in which the GPS technology is integrated into a firm's information management or dispatch system. The key to effective utilization of the new technology is the linkage into the firm's decision making system. Future research should examine this link. Additionally, an effort should be made to identify quantifiable measures of effectiveness for various selected variables including productivity, customer service, firm size and type. A deliberate survey of non-users would also be appropriate with perhaps a detailed follow-up survey to firms who have made analysis of the technology and decided *not* to the acquire the systems or to *delay* their implementation. In this manner analysts can better identify barriers to entry and identify procedures for eliminating the barriers.

A similar process needs to be conducted for military organizations. One of the recent problems in low-intensity operations has been inter-service communications. In addition to a deliberate survey of requirements for logisticians, customers, and commanders in the Army, a deliberate process must be made so that Marines can employ GPS and communications technology acquired by the Army or the Air Force.

Once again the critical links between the GPS elements and the various tactical command and control systems should be examined. These links could and should be linked with advances in Geographical Information Systems and other cartographic technologies.

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Appendix A: COVER LETTER TO SURVEY

PENNSTATE

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Department of Business Logistics
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College of Business Administration

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May 1, 1996

Dear Transportation Professional:

Your assistance is requested in the data collection portion of a research project. Attached is a questionnaire that has been prepared by Ms. Catherine A. Yarberry, a graduate student in the Business Logistics Department at Penn State University. Ms. Yarberry's thesis deals with measuring the perceived benefits associated with the use of satellite tracking systems in the commercial trucking industry. Specifically, the intent of her research is to gain a better understanding of the asset tracking systems currently available in the commercial sector, and to access the value of this technology as perceived by participants in the transportation process.

This survey is being sent to experts in the commercial trucking industry, such as yourself, in order to solicit opinions regarding the importance or non-importance of certain benefits commonly associated with the use of satellite tracking systems. Please take a few minutes to complete the attached questionnaire and return by **June 3, 1996** in the envelope provided. Your participation is voluntary and your responses will be kept strictly confidential. The number found on the last page of the questionnaire is being used to track the number of those survey respondents who do not currently use satellite tracking technology, and will not be used to specifically associate or identify your company with particular responses.

It is our hope that you will personally answer the questionnaire, but if you think others in your organization will be better able to answer the questions, please feel free to forward the questionnaire. Thank you in advance for your help and support of this research project.

Sincerely,

Lisa Williams Walton

Lisa Williams-Walton, Ph.D.
Assistant Professor of Business Logistics

Catherine A. Yarberry

Catherine A. Yarberry
Masters' Candidate Business Logistics

Enclosures

Appendix B: SURVEY SENT TO CONTINENTAL U.S. MEMBERS OF THE AMERICAN MOTOR CARRIER ASSOCIATION

Satellite Tracking Systems Questionnaire

Lisa Williams-Walton
Assistant Professor of Business Logistics

Catherine A. Yarberry
Masters' Candidate–Business Logistics

The Pennsylvania State University
The Smeal College of Business Administration
509 Business Administration Building
University Park, PA 16802-3005

In recent years, a number of firms within our nation's trucking industry have incorporated satellite technology to track assets that are "on the move." This survey asks for your ideas regarding actual or perceived benefits associated with satellite tracking systems in the transportation process.

Please circle the appropriate number following each statement to indicate your **agreement** or **disagreement** with the statement. If your company does not currently use satellite tracking systems, please skip to ***Question 25***.

		Strongly Disagree				Strongly Agree
1.	The use of satellite tracking systems allows drivers to spend more time "behind the wheel" rather than "on the phone."	1	2	3	4	5
2.	There has been relatively little change in the number of deliveries per driver/per day since the incorporation of satellite tracking systems.	1	2	3	4	5
3.	Customers are better serviced because of satellite tracking systems.	1	2	3	4	5
4.	Inventory holding costs, such as warehouse expenses, decrease when satellite tracking systems are used.	1	2	3	4	5
5.	Satellite tracking systems permit more timely reporting of maintenance problems.	1	2	3	4	5
6.	The road maps and/or directions provided by satellite tracking systems result in fewer "dead miles" per driver.	1	2	3	4	5
7.	Customers seek out carriers that use satellite tracking systems.	1	2	3	4	5
8.	Labor costs decrease when a trucking firm uses satellite tracking technology.	1	2	3	4	5
9.	The use of satellite tracking systems permits the re-routing of drivers when necessary.	1	2	3	4	5

		Strongly Disagree				Strongly Agree
10.	Customers feel that they have more control over their inventory when carriers use satellite tracking systems.	1	2	3	4	5
11.	Customer demand increases when a trucking firm uses satellite tracking systems.	1	2	3	4	5
12.	Drivers are able to locate addresses more quickly due to satellite tracking systems.	1	2	3	4	5
13.	Truck utilization is maximized by using satellite tracking systems.	1	2	3	4	5
14.	Satellite tracking systems allow customers greater visibility of their in-transit assets.	1	2	3	4	5
15.	Telephone costs for a trucking firm decrease when satellite tracking systems are used.	1	2	3	4	5
16.	Before the incorporation of satellite technology, drivers often lost time waiting to be loaded or unloaded by unprepared shippers.	1	2	3	4	5
17.	Drivers favor the use of satellite tracking systems.	1	2	3	4	5
18.	Satellite tracking systems allow for real-time response to spot order service requests.	1	2	3	4	5
19.	Drivers spend less time trying to contact their dispatcher due to satellite tracking systems.	1	2	3	4	5
20.	Driver turnover decreases when satellite tracking systems are used.	1	2	3	4	5
21.	My company is satisfied with the benefits provided by satellite tracking technology.	1	2	3	4	5
22.	Satellite tracking technology is considered to be of value to my company.	1	2	3	4	5

Circle Number of Years

23. Please indicate the number of years that your company has used satellite tracking systems. 1-2 2-4 4-6 6-8 8+

Circle Percentage

24. Please indicate the percentage of your company's fleet that is currently equipped with satellite tracking equipment. 1-25 25-50 50-75 75+ 100

25. If *not* currently using satellite tracking systems, which of the following does your company use?

   a. cellular (land based) communications
   b. pager or beeper systems
   c. meteor burst technology
   d. other (please specify) ____

26. Why has your company decided against the use of satellite tracking systems?

____
____
____
____
____
____
____
____

Thank you for taking the time to complete this survey. Your input is greatly appreciated. If you would be interested in a copy of the survey results, please enclose your business card or provide your name and address below. Additionally, if there is a point of contact at your company willing to share *specific* information with this researcher regarding savings, increased productivity or other benefits resulting from your company's use of satellite technology, please provide a name, address, and phone number below:

Name: ____

Address: ____
____
____

Phone: ______________________________

Thank you for taking the time to complete this survey. Your input is greatly appreciated.

Please return this completed survey in the envelope provided.

SURV NO	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	TimeSav	IncrProd	CustSvc	IncrROI	Satisf	Value	LengUse	No. Veh
10	5	4	2	2	5	5	4	3	5	4	3	4	4	4	4	3	4	3	4	*	21	22	17	*	5	5	5	5
12	5	4	3	1	5	5	3	3	5	4	3	3	4	4	3	4	3	4	3	*	20	21	18	*	5	5	5	5
24	5	2	4	*	4	*	3	3	4	*	3	*	*	3	4	*	4	4	5	*	*	*	*	*	4	5	3	2
33	4	4	4	3	4	4	3	3	3	4	4	3	3	4	3	2	2	4	3	2	16	16	19	15	3	*	1	1
35	5	3	5	3	3	4	5	4	5	4	5	4	5	5	4	5	5	5	5	2	22	22	24	18	5	5	2	5
42	3	4	4	4	5	4	3	3	5	4	3	4	4	4	3	4	4	4	4	3	20	21	19	16	4	4	1	1
84	5	*	4	*	4	*	3	4	5	3	3	*	4	4	4	*	3	4	4	3	*	*	18	*	4	4	1	2
95	4	2	5	3	5	4	3	4	5	4	5	3	5	4	2	5	4	5	5	3	22	20	21	17	4	4	5	4
147F	*	*	5	*	4	3	3	3	5	5	3	3	4	4	3	3	2	4	5	*	*	*	21	*	2	2	1	1
161	5	2	5	1	5	5	5	4	5	5	4	5	5	3	5	4	5	3	5	4	24	22	21	18	5	5	2	5
184F	4	4	3	2	3	1	3	1	4	4	3	3	1	4	1	1	3	4	4	1	15	13	18	8	2	2	2	5
189F	5	2	4	4	4	3	3	4	5	5	2	3	3	3	3	4	3	4	5	3	21	16	19	16	3	4	1	1
193	5	3	5	3	4	3	4	4	4	3	3	4	3	3	2	2	4	3	5	4	20	17	18	16	4	4	2	5
200	5	3	4	3	4	3	3	3	5	4	3	3	4	4	4	4	5	5	5	3	21	20	20	16	4	5	2	4
218F	4	2	5	2	5	4	3	4	5	4	3	3	3	3	5	4	1	4	5	2	21	15	19	16	4	4	3	4
219	5	3	5	3	4	4	4	5	5	5	4	4	4	5	3	2	5	5	5	1	20	21	24	16	5	5	3	3
220	4	3	4	2	3	4	3	3	5	2	1	1	4	5	3	3	3	3	3	1	14	19	17	10	5	5	2	2
222	4	3	5	2	4	4	1	3	5	2	1	3	3	4	3	*	4	4	4	1	*	19	16	10	4	4	2	3
277F	2	3	4	4	5	4	3	4	5	4	4	4	2	4	5	5	2	4	5	2	21	16	19	19	3	3	1	3
281	3	2	5	3	1	3	3	3	4	5	4	3	4	5	3	4	3	4	3	2	14	16	22	15	4	4	1	3
301	2	5	2	1	1	1	1	1	4	3	1	3	3	3	4	3	1	3	2	1	11	14	12	8	2	1	1	1
310F	3	3	5	2	3	5	2	2	3	2	2	3	2	3	5	3	2	3	3	2	15	15	15	13	3	3	1	1
347	5	3	5	3	4	5	4	4	5	5	5	5	5	3	4	3	4	4	5	4	22	22	21	20	5	5	1	1
358	3	3	3	1	2	4	3	4	5	3	5	4	4	2	2	3	2	4	4	1	16	18	15	13	3	2	1	1
366F	4	5	4	3	4	4	4	4	4	4	2	4	4	3	4	4	4	4	5	3	21	21	19	16	4	4	2	1
383	5	2	4	3	5	5	4	4	5	4	4	4	4	4	4	3	4	4	5	3	22	20	20	18	4	4	1	1
409	5	2	5	*	4	3	5	2	5	4	3	3	5	5	2	3	3	3	4	3	19	18	22	*	4	4	1	5
493	3	2	2	3	2	2	3	3	2	3	3	2	2	2	2	2	2	2	2	3	11	10	12	14	3	3	1	1

Summation of Questions for Ind. Variables

Time Savings	= Q1+Q5+Q12+Q16+Q19
Increased Producivity	= Q2+Q6+Q 9+Q13+Q17
Impr. Cust. Service	= Q3+Q7+Q10+Q14+Q18
Increased ROI	= Q4+Q8+Q11+Q15+Q20

Coding for Response Variables

Satisfaction & Value

Direct survey response

Length of Use

1 1-2 years
2 2-4 years
3 4-6 years
4 6-8 years
5 8+ years

No of Vehicles Equipped

1 1-25 %
2 25-50 %
3 50-75 %
4 75-99 %
5 100 %

Appendix D: MODEL 1 - STATISTICAL ANALYSIS AND MODEL BUILDING

Statistical Analysis and Model Building - Satisfaction

Step 1 Identify Independent Variables & Interaction Terms

Correlations (Pearson)

	Satisf	TimeSav	IncrProd	CustSvc	XX_TSCS	XX_TSROI	XX_IPCS	XX_IPROI
TimeSav	0.585^{7}							
IncrProd	0.809^{1}	**0.737**						
CustSvc	0.461^{8}	**0.675**	**0.582**					
XX_TSCS	0.638^{5}	~~0.932~~	**0.737**	~~0.885~~				
XX_TSROI	0.608^{6}	~~0.955~~	**0.697**	**0.702**	~~0.919~~			
XX_IPCS	0.788^{2}	**0.776**	~~0.890~~	~~0.876~~	~~0.902~~	**0.760**		
XX_IPROI	0.729^{4}	**0.874**	~~0.843~~	**0.763**	**0.898**	~~0.930~~	~~0.893~~	
XXXXTPSR	0.745^{3}	~~0.898~~	~~0.851~~	~~0.810~~	~~0.950~~	~~0.929~~	~~0.921~~	~~0.972~~

Superscripted numbers indicate variable entry order based on strength of correlation with response variable (satisfaction). Step-wise regression not possible due to multicollinearity. Model must be manually built.

Best Subsets Regression (Refined Variable Set - Satisfaction)

Response is Satisfaction

21 cases used 7 cases contain missing values.

Vars	R-sq	Adj. R-sq	C-p	s	TimeSav	IncrProd	CustSvc	XX_TSCS	XX_TSROI	XX_IPCS	XX_IPROI	XXXXTPSR
1	67.3	65.6	7.8	0.55334						X		
1	61.9	59.9	11.9	0.59767		X						
2	69.1	65.7	8.4	0.55274				X		X		
2	69.0	65.5	8.5	0.55405			X			X		
3	71.6	66.6	8.5	0.54515				X	X	X		
3	70.5	65.3	9.4	0.55619				X		X	X	
4	77.4	71.8	6.1	0.50132				X	X	X	X	
4	72.1	65.1	10.2	0.55749		X		X	X	X		
5	77.6	70.1	~~8.0~~	0.51595		X		X	X	X	X	
5	77.6	70.1	8.0	0.51621				X	X	X	X	X
6	80.7	72.4	~~7.6~~	0.49536	X	X		X	X	X	X	
6	78.7	69.5	9.2	0.52097		X	X	X	X	X	X	
7	**84.2**	**75.7**	**7.0**	**0.46554**	**X**	**X**		**X**	**X**	**X**	**X**	**X**
7	83.4	74.5	7.6	0.47685	X	X	X	X	X	X	X	
8	84.2	73.6	~~9.0~~	0.48450	X	X	X	X	X	X	X	X

Step 2 - Identify Principle Independent Variable

A. Regression Analysis

The regression equation is
Satisf = - 0.312 + 0.231 IncrProd

25 cases used 3 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	
Constant	-0.3117	0.6454	-0.48	0.634	
IncrProd	0.23082	0.03501	6.59	0.000	**p < 0.05 ∴ Signif. Var.**

s = 0.5572 R-sq = 65.4% **R-sq(adj) = 63.9%**

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	13.498	13.498	43.47	0.000
Error	23	7.142	0.311		
Total	24	20.640			

Unusual Observations

Obs.	IncrProd	Satisf	Fit	Stdev.Fit	Residual	St.Resid
28	10.0	3.000	1.997	0.307	1.003	2.16RX

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

No evidence of lack of fit (P > 0.1)

B. Regression Analysis

The regression equation is
Satisf = 1.33 + 0.00739 XX_IPCS

25 cases used 3 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	
Constant	1.3333	0.4313	3.09	0.005	
XX_IPCS	0.007385	0.001204	6.13	0.000	**p < 0.05 ∴ Signif. Var.**

s = 0.5835 R-sq = 62.1% **R-sq(adj) = 60.4%**

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	12.810	12.810	37.63	0.000
Error	23	7.830	0.340		
Total	24	20.640			

Unusual Observations

Obs.	XX_IPCS	Satisf	Fit	Stdev.Fit	Residual	St.Resid
17	323	5.000	3.719	0.120	1.281	2.24R
28	120	3.000	2.220	0.295	0.780	1.55 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.
No evidence of lack of fit (P > 0.1)

C. Regression Analysis

The regression equation is
Satisf = 2.52 +0.000012 XXXXTPSR

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	
Constant	2.5197	0.2914	8.65	0.000	
XXXXTPSR	0.00001157	0.00000238	4.87	0.000	**p < 0.05 ∴ Signif. Var.**

s = 0.6458 R-sq = 55.5% **R-sq(adj) = 53.2%**

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	9.8865	9.8865	23.71	0.000
Error	19	7.9231	0.4170		
Total	20	17.8095			

Unusual Observations

Obs.	XXXXTPSR	Satisf	Fit	Stdev.Fit	Residual	St.Resid
17	45220	5.000	3.043	0.204	1.957	3.19R

R denotes an obs. with a large st. resid.

No evidence of lack of fit (P > 0.1)

D. Regression Analysis

The regression equation is
Satisf = 1.81 + 0.00721 XX_IPROI

22 cases used 6 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	
Constant	1.8130	0.4342	4.18	0.000	
XX_IPROI	0.007213	0.001515	4.76	0.000	**p < 0.05 ∴ Signif. Var.**

s = 0.6471 R-sq = 53.1% R-sq(adj) = 50.8%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	9.4887	9.4887	22.66	0.000
Error	20	8.3750	0.4187		
Total	21	17.8636			

Unusual Observations

Obs.	XX_IPROI	Satisf	Fit	Stdev.Fit	Residual	St.Resid
17	190	5.000	3.184	0.185	1.816	2.93R

R denotes an obs. with a large st. resid.

No evidence of lack of fit (P > 0.1)

E. Regression Analysis

The regression equation is
Satisf = 1.87 + 0.00558 XX_TSCS

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	
Constant	1.8722	0.5379	3.48	0.002	
XX_TSCS	0.005579	0.001437	3.88	0.001	**p < 0.05 ∴ Signif. Var.**

s = 0.7459   R-sq = 40.7%   R-sq(adj) = 38.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	8.3848	8.3848	15.07	0.001
Error	22	12.2402	0.5564		
Total	23	20.6250			

Unusual Observations

Obs.	XX_TSCS	Satisf	Fit	Stdev.Fit	Residual	St.Resid
17	238	5.000	3.200	0.231	1.800	2.54R

R denotes an obs. with a large st. resid.

No evidence of lack of fit (P > 0.1)

F. Regression Analysis

The regression equation is
Satisf = 2.21 + 0.00534 XX_TSROI

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	
Constant	2.2116	0.4942	4.48	0.000	
XX_TSROI	0.005340	0.001601	3.34	0.003	**p < 0.05 ∴ Signif. Var.**

s = 0.7689   R-sq = 36.9%   R-sq(adj) = 33.6%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	6.5764	6.5764	11.12	0.003
Error	19	11.2331	0.5912		
Total	20	17.8095			

Unusual Observations

Obs.	XX_TSROI	Satisf	Fit	Stdev.Fit	Residual	St.Resid
17	140	5.000	2.959	0.293	2.041	2.87R

R denotes an obs. with a large st. resid.

No evidence of lack of fit (P > 0.1)

G. Regression Analysis

The regression equation is
Satisf = 1.08 + 0.150 TimeSav

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	
Constant	1.0758	0.8434	1.28	0.215	
TimeSav	0.14962	0.04426	3.38	0.003	**$p < 0.05$ ∴ Signif. Var.**

s = 0.7855   R-sq = 34.2%   R-sq(adj) = 31.2%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	7.0510	7.0510	11.43	0.003
Error	22	13.5740	0.6170		
Total	23	20.6250			

Unusual Observations

Obs.	TimeSav	Satisf	Fit	Stdev.Fit	Residual	St.Resid
17	14.0	5.000	3.171	0.263	1.829	2.47R

R denotes an obs. with a large st. resid.

No evidence of lack of fit (P > 0.1)

H. Regression Analysis

The regression equation is
Satisf = 1.05 + 0.148 CustSvc

27 cases used 1 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	
Constant	1.049	1.077	0.97	0.339	
CustSvc	0.14756	0.05678	2.60	0.015	**$p < 0.05$ ∴ Signif. Var.**

s = 0.8707   R-sq = 21.3%   R-sq(adj) = 18.1%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	5.1208	5.1208	6.75	0.015
Error	25	18.9532	0.7581		
Total	26	24.0741			

Unusual Observations

Obs.	CustSvc	Satisf	Fit	Stdev.Fit	Residual	St.Resid
9	21.0	2.000	4.148	0.211	-2.148	-2.54R
21	12.0	2.000	2.820	0.418	-0.820	-1.07 X
28	12.0	3.000	2.820	0.418	0.180	0.24 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

No evidence of lack of fit (P > 0.1)

I. Regression Analysis

The regression equation is
Satisf = 1.59 + 0.146 IncrROI

22 cases used 6 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	
Constant	1.5887	0.7953	2.00	0.060	
IncrROI	0.14649	0.05210	2.81	0.011	**$p < 0.05$ ∴ Signif. Var.**

s = 0.8001 R-sq = 28.3% R-sq(adj) = 24.7%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	5.0606	5.0606	7.91	0.011
Error	20	12.8030	0.6402		
Total	21	17.8636			

Unusual Observations

Obs.	IncrROI	Satisf	Fit	Stdev.Fit	Residual	St.Resid
17	10.0	5.000	3.054	0.307	1.946	2.64R

R denotes an obs. with a large st. resid.
Possible lack of fit at outer X-values (P = 0.003)
Overall lack of fit test is significant at P = 0.003

Step 2 Summary

Satisfaction 1-Variable	**Adjusted r^2**	**p-value**
IncrProd	**63.9**	.000
XX_IPCS Interaction	60.4	.000
XXXXTPSR Interaction	53.2	.000
XX_IPROI Interaction	50.8	.000
XX_TSCS Interaction	38.0	.001
XX_TSROI Interaction	33.6	.003
TimeSav	31.2	.003
CustSvc	18.1	.015
IncrROI	24.7	.011

Select IncrProd as principle variable.

Step 3 Identify Secondary Variables

A. Regression Analysis

The regression equation is
Satisf = 0.140 + 0.148 IncrProd + 0.00307 XX_IPCS

25 cases used 3 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	0.1403	0.7365	0.19	0.851	
IncrProd	0.14766	0.07595	1.94	0.065	4.8
XX_IPCS	0.003069	0.002494	1.23	0.232	4.8 **p>0.05 Reject**

s = 0.5511   R-sq = 67.6%   R-sq(adj) = 64.7%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	13.9580	6.9790	22.98	0.000
Error	22	6.6820	0.3037		
Total	24	20.6400			

SOURCE	DF	SEQ SS
IncrProd	1	13.4982
XX_IPCS	1	0.4597

Unusual Observations

Obs.	IncrProd	Satisf	Fit	Stdev.Fit	Residual	St.Resid
17	19.0	5.000	3.937	0.159	1.063	2.01R
28	10.0	3.000	1.985	0.303	1.015	2.21R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

B. Regression Analysis

The regression equation is
Satisf = 0.546 + 0.155 IncrProd +0.000004 XXXXTPSR

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	0.5456	0.9975	0.55	0.591	
IncrProd	0.15492	0.07537	2.06	0.055	3.6
XXXXTPSR	0.00000426	0.00000418	1.02	0.322	3.6 **p>0.05 Reject**

s = 0.5971   R-sq = 64.0%   R-sq(adj) = 60.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	11.3927	5.6963	15.98	0.000
Error	18	6.4168	0.3565		
Total	20	17.8095			

SOURCE	DF	SEQ SS
IncrProd	1	11.0226
XXXXTPSR	1	0.3701

Unusual Observations

Obs.	IncrProd	Satisf	Fit	Stdev.Fit	Residual	St.Resid
17	19.0	5.000	3.682	0.364	1.318	2.78R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

C. Regression Analysis

The regression equation is
Satisf = 0.182 + 0.167 IncrProd + 0.00223 XX_IPROI

22 cases used 6 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	0.1823	0.8053	0.23	0.823	
IncrProd	0.16715	0.07204	2.32	0.032	3.5
XX_IPROI	0.002225	0.002551	0.87	0.394	3.5 **p>0.05 Reject**

s = 0.5861   R-sq = 63.5%   R-sq(adj) = 59.6%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	11.3377	5.6688	16.50	0.000
Error	19	6.5260	0.3435		
Total	21	17.8636			

SOURCE	DF	SEQ SS
IncrProd	1	11.0762
XX_IPROI	1	0.2614

Unusual Observations

Obs.	IncrProd	Satisf	Fit	Stdev.Fit	Residual	St.Resid
17	19.0	5.000	3.781	0.307	1.219	2.44R

R denotes an obs. with a large st. resid.

Lack of fit test
Possible interactions with variable IncrProd (P = 0.095)
Overall lack of fit test is significant at P = 0.095

D. Regression Analysis

The regression equation is
Satisf = - 0.252 + 0.212 IncrProd + 0.00080 XX_TSCS

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	-0.2517	0.6836	-0.37	0.716	
IncrProd	0.21190	0.05396	3.93	0.001	2.2
XX_TSCS	0.000797	0.001652	0.48	0.635	2.2 **p>0.05 Reject**

s = 0.5797   R-sq = 65.8%   R-sq(adj) = 62.5%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	13.5671	6.7835	20.18	0.000
Error	21	7.0579	0.3361		
Total	23	20.6250			

SOURCE	DF	SEQ SS
IncrProd	1	13.4889
XX_TSCS	1	0.0781

Unusual Observations

Obs.	IncrProd	Satisf	Fit	Stdev.Fit	Residual	St.Resid
17	19.0	5.000	3.964	0.265	1.036	2.01R
28	10.0	3.000	1.972	0.323	1.028	2.14R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

E. Regression Analysis

The regression equation is
Satisf = - 0.054 + 0.198 IncrProd + 0.00101 XX_TSROI

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	-0.0540	0.7544	-0.07	0.944	
IncrProd	0.19775	0.05630	3.51	0.002	1.9
XX_TSROI	0.001013	0.001768	0.57	0.574	1.9 **p>0.05 Reject**

s = 0.6085   R-sq = 62.6%   R-sq(adj) = 58.4%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	11.1442	5.5721	15.05	0.000
Error	18	6.6653	0.3703		
Total	20	17.8095			

SOURCE	DF	SEQ SS
IncrProd	1	11.0226
XX_TSROI	1	0.1216

Unusual Observations

Obs.	IncrProd	Satisf	Fit	Stdev.Fit	Residual	St.Resid
17	19.0	5.000	3.845	0.343	1.155	2.30R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

F. Regression Analysis

The regression equation is
Satisf = - 0.289 + 0.236 IncrProd - 0.0063 TimeSav

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	-0.2892	0.6997	-0.41	0.684	
IncrProd	0.23627	0.05424	4.36	0.000	2.2
TimeSav	-0.00632	0.04857	-0.13	0.898	2.2 **p>0.05 Reject**

s = 0.5827   R-sq = 65.4%   R-sq(adj) = 62.1%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	13.4947	6.7473	19.87	0.000
Error	21	7.1303	0.3395		
Total	23	20.6250			

SOURCE	DF	SEQ SS
IncrProd	1	13.4889
TimeSav	1	0.0057

Unusual Observations

Obs.	IncrProd	Satisf	Fit	Stdev.Fit	Residual	St.Resid
28	10.0	3.000	2.004	0.325	0.996	2.06R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

G. Regression Analysis

The regression equation is
Satisf = - 0.690 + 0.207 IncrProd + 0.0439 CustSvc

25 cases used 3 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	-0.6902	0.7552	-0.91	0.371	
IncrProd	0.20652	0.04310	4.79	0.000	1.5
CustSvc	0.04389	0.04529	0.97	0.343	1.5 **p>0.05 Reject**

s = 0.5580   R-sq = 66.8%   R-sq(adj) = 63.8%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	13.7906	6.8953	22.15	0.000
Error	22	6.8494	0.3113		
Total	24	20.6400			

SOURCE	DF	SEQ SS
IncrProd	1	13.4982
CustSvc	1	0.2923

Unusual Observations

Obs.	IncrProd	Satisf	Fit	Stdev.Fit	Residual	St.Resid
28	10.0	3.000	1.902	0.322	1.098	2.41R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

H. Regression Analysis

The regression equation is
Satisf = - 0.441 + 0.195 IncrProd + 0.0493 IncrROI

22 cases used 6 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	-0.4407	0.7382	-0.60	0.558	
IncrProd	0.19475	0.04441	4.39	0.000	1.3
IncrROI	0.04927	0.04372	1.13	0.274	1.3 **p>0.05 Reject**

s = 0.5787   R-sq = 64.4%   R-sq(adj) = 60.6%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	11.5014	5.7507	17.17	0.000
Error	19	6.3622	0.3349		
Total	21	17.8636			

SOURCE	DF	SEQ SS
IncrProd	1	11.0762
IncrROI	1	0.4252

Unusual Observations

Obs.	IncrProd	Satisf	Fit	Stdev.Fit	Residual	St.Resid
17	19.0	5.000	3.752	0.274	1.248	2.45R

R denotes an obs. with a large st. resid.

Lack of fit test
Possible interactions with variable IncrProd (P = 0.095)
Overall lack of fit test is significant at P = 0.095

Summary Step 3

Satisfaction 2-Variable IncrProd +	Adjusted R^2	p-value
XX_IPCS Interaction	NA	.232
XXXXTPSR Interaction	NA	.322
XX_IPROI Interaction	NA	.394
XX_TSCS Interaction	NA	.635
XX_TSROI Interaction	NA	.574
TimeSav	NA	.898
CustSvc	NA	.343
IncrROI	NA	.274

Reject all variables. Final model for *Satisfaction* is:

$$\textbf{\textit{Satisfaction}} = -0.312 + 0.231\ \textbf{\textit{Increased Productivity}}$$

Appendix E: MODEL 2 - STATISTICAL ANALYSIS AND MODEL BUILDING

Statistical Analysis and Model Building - Value

Step 1 Identify Independent Variables & Interaction Terms

Correlations (Pearson)

	Value	TimeSav	IncrProd	CustSvc	IncrROI	XX_TSIP	XX_TSCS	XX_TSROI
TimeSav	0.645							
IncrProd	0.727	**0.737**						
CustSvc	0.546	**0.675**	**0.582**					
IncrROI	0.591	**0.808**	**0.507**	**0.649**				
XX_TSIP	0.737	0.927	0.926	0.666	0.755			
XX_TSCS	0.698	0.932	0.737	0.885	0.795	0.891		
XX_TSROI	0.654	0.955	0.697	0.702	0.938	0.898	0.919	
XX_IPCS	0.771	0.776	0.890	0.876	0.646	0.895	0.902	0.760
XX_IPROI	0.710	0.874	0.843	0.763	0.882	0.953	0.898	0.930
XX_CSROI	0.702	0.847	0.655	0.879	0.927	0.843	0.931	0.923
XXXXTPSR	0.734	0.898	0.851	0.810	0.837	0.960	0.950	0.929

	XX_IPCS	XX_IPROI	XX_CSROI
XX_IPROI	0.893		
XX_CSROI	0.846	0.925	
XXXXTPSR	0.921	0.972	0.932

Step 2 - Identify Principle Independent Variable

A. Regression Analysis

```
The regression equation is
Value = 0.999 + 0.00842 XX_IPCS

24 cases used 4 cases contain missing values

Predictor        Coef        Stdev     t-ratio        p
Constant       0.9985       0.5348        1.87    0.075
XX_IPCS      0.008421     0.001485        5.67    0.000

s = 0.7168      R-sq = 59.4%     R-sq(adj) = 57.5%

Analysis of Variance

SOURCE        DF          SS          MS         F        p
Regression     1      16.531      16.531     32.18    0.000
Error         22      11.303       0.514
Total         23      27.833

Unusual Observations
Obs.  XX_IPCS       Value       Fit  Stdev.Fit   Residual    St.Resid
 21       168       1.000     2.413      0.303     -1.413      -2.18R
 28       120       3.000     2.009      0.367      0.991       1.61 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.
```

B. Regression Analysis

The regression equation is
Value = 1.37 + 0.00724 XX_TSIP

23 cases used 5 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	1.3657	0.5346	2.55	0.018
XX_TSIP	0.007242	0.001448	5.00	0.000

s = 0.7777   R-sq = 54.4%   R-sq(adj) = 52.2%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	15.125	15.125	25.01	0.000
Error	21	12.701	0.605		
Total	22	27.826			

Unusual Observations

Obs.	XX_TSIP	Value	Fit	Stdev.Fit	Residual	St.Resid
17	266	5.000	3.292	0.204	1.708	2.28R
21	154	1.000	2.481	0.329	-1.481	-2.10R

R denotes an obs. with a large st. resid.

Regression Analysis

The regression equation is
Value = 2.31 +0.000014 XXXXTPSR

20 cases used 8 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	2.3090	0.3718	6.21	0.000
XXXXTPSR	0.00001366	0.00000298	4.58	0.000

s = 0.8039   R-sq = 53.8%   R-sq(adj) = 51.3%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	13.566	13.566	20.99	0.000
Error	18	11.634	0.646		
Total	19	25.200			

Unusual Observations

Obs.	XXXXTPSR	Value	Fit	Stdev.Fit	Residual	St.Resid
17	45220	5.000	2.927	0.262	2.073	2.73R
21	14784	1.000	2.511	0.334	-1.511	-2.07R

R denotes an obs. with a large st. resid.

D. Regression Analysis

The regression equation is
Value = - 0.526 + 0.243 IncrProd

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	-0.5265	0.9073	-0.58	0.568
IncrProd	0.24346	0.04896	4.97	0.000

s = 0.7718 R-sq = 52.9% R-sq(adj) = 50.8%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	14.729	14.729	24.73	0.000
Error	22	13.104	0.596		
Total	23	27.833			

Unusual Observations

Obs.	IncrProd	Value	Fit	Stdev.Fit	Residual	St.Resid
21	14.0	1.000	2.882	0.261	-1.882	-2.59R
24	18.0	2.000	3.856	0.158	-1.856	-2.46R
28	10.0	3.000	1.908	0.434	1.092	1.71 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

E. Regression Analysis

The regression equation is
Value = 1.52 + 0.00838 XX_IPROI

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	1.5195	0.5497	2.76	0.012
XX_IPROI	0.008382	0.001905	4.40	0.000

s = 0.8111 R-sq = 50.5% R-sq(adj) = 47.9%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	12.739	12.739	19.37	0.000
Error	19	12.499	0.658		
Total	20	25.238			

Unusual Observations

Obs.	XX_IPROI	Value	Fit	Stdev.Fit	Residual	St.Resid
17	190	5.000	3.112	0.238	1.888	2.43R

R denotes an obs. with a large st. resid.

F. Regression Analysis

The regression equation is
Value = 1.53 + 0.00800 XX_CSROI

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	1.5328	0.5601	2.74	0.013
XX_CSROI	0.008003	0.001865	4.29	0.000

s = 0.8213   R-sq = 49.2%   R-sq(adj) = 46.5%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	12.420	12.420	18.41	0.000
Error	19	12.818	0.675		
Total	20	25.238			

Unusual Observations

Obs.	XX_CSROI	Value	Fit	Stdev.Fit	Residual	St.Resid
17	170	5.000	2.893	0.279	2.107	2.73R

R denotes an obs. with a large st. resid.

G. Regression Analysis

The regression equation is
Value = 1.33 + 0.00714 XX_TSCS

23 cases used 5 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	1.3345	0.6024	2.22	0.038
XX_TSCS	0.007135	0.001598	4.47	0.000

s = 0.8244   R-sq = 48.7%   R-sq(adj) = 46.3%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	13.555	13.555	19.95	0.000
Error	21	14.271	0.680		
Total	22	27.826			

Unusual Observations

Obs.	XX_TSCS	Value	Fit	Stdev.Fit	Residual	St.Resid
17	238	5.000	3.033	0.262	1.967	2.52R

R denotes an obs. with a large st. resid.

H. Regression Analysis

The regression equation is
Value = 1.79 + 0.00688 XX_TSROI

20 cases used 8 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	1.7868	0.5844	3.06	0.007
XX_TSROI	0.006876	0.001875	3.67	0.002

s = 0.8952   R-sq = 42.8%   R-sq(adj) = 39.6%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	10.776	10.776	13.45	0.002
Error	18	14.424	0.801		
Total	19	25.200			

Unusual Observations

Obs.	XX_TSROI	Value	Fit	Stdev.Fit	Residual	St.Resid
17	140	5.000	2.749	0.350	2.251	2.73R

R denotes an obs. with a large st. resid.

I. Regression Analysis

The regression equation is
Value = 0.259 + 0.194 TimeSav

23 cases used 5 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	0.2586	0.9622	0.27	0.791
TimeSav	0.19411	0.05018	3.87	0.001

s = 0.8796   R-sq = 41.6%   R-sq(adj) = 38.8%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	11.579	11.579	14.97	0.001
Error	21	16.247	0.774		
Total	22	27.826			

Unusual Observations

Obs.	TimeSav	Value	Fit	Stdev.Fit	Residual	St.Resid
17	14.0	5.000	2.976	0.304	2.024	2.45R

R denotes an obs. with a large st. resid.

J. Regression Analysis

The regression equation is
Value = 0.926 + 0.193 IncrROI

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	0.9261	0.9246	1.00	0.329
IncrROI	0.19346	0.06052	3.20	0.005

s = 0.9294   R-sq = 35.0%   R-sq(adj) = 31.5%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	8.8253	8.8253	10.22	0.005
Error	19	16.4128	0.8638		
Total	20	25.2381			

Unusual Observations

Obs.	IncrROI	Value	Fit	Stdev.Fit	Residual	St.Resid
17	10.0	5.000	2.861	0.360	2.139	2.50R

R denotes an obs. with a large st. resid.

K. Regression Analysis

The regression equation is
Value = 0.11 + 0.200 CustSvc

26 cases used 2 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	0.108	1.185	0.09	0.928
CustSvc	0.19957	0.06247	3.19	0.004

s = 0.9579   R-sq = 29.8%   R-sq(adj) = 26.9%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	9.3647	9.3647	10.21	0.004
Error	24	22.0200	0.9175		
Total	25	31.3846			

Unusual Observations

Obs.	CustSvc	Value	Fit	Stdev.Fit	Residual	St.Resid
9	21.0	2.000	4.299	0.235	-2.299	-2.48R
21	12.0	1.000	2.503	0.461	-1.503	-1.79 X
28	12.0	3.000	2.503	0.461	0.497	0.59 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

Summary Step 2

Satisfaction 1-Variable	Adjusted r^2	p-value
XX_IPCS Interaction	**57.5**	.000
XX_TSI Interaction	52.2	.000
XXXXTPSR Interaction	51.3	.000
IncrProd	50.8	.000
XX_IPROI Interaction	47.9	.000
XX_CSROI Interaction	46.5	.000
XX_TSCS Interaction	46.3	.000
XX_TSROI Interaction	39.6	.002
TimeSav	38.8	.001
IncrROI	31.5	.005
CustSvc	26.9	.004

Select *Increased Productivity / Customer Service* interaction term as primary variable.

Step 3 Identify Secondary Variables

A. Regression Analysis

```
The regression equation is
Value = 0.944 + 0.00640 XX_IPCS + 0.00211 XX_TSIP

23 cases used 5 cases contain missing values

Predictor        Coef       Stdev    t-ratio       p
Constant       0.9438      0.5553       1.70   0.105
XX_IPCS      0.006397    0.003461       1.85   0.079
XX_TSIP      0.002105    0.003099       0.68   0.505

s = 0.7365      R-sq = 61.0%      R-sq(adj) = 57.1%

Analysis of Variance

SOURCE       DF         SS         MS        F        p
Regression    2    16.9787     8.4894    15.65    0.000
Error        20    10.8474     0.5424
Total        22    27.8261

SOURCE       DF     SEQ SS
XX_IPCS       1    16.7284
XX_TSIP       1     0.2503

Unusual Observations
Obs.  XX_IPCS      Value        Fit  Stdev.Fit   Residual    St.Resid
 17       323      5.000      3.570      0.245      1.430       2.06R
 21       168      1.000      2.343      0.320     -1.343      -2.03R

R denotes an obs. with a large st. resid.
```

B. Regression Analysis

The regression equation is
Value = 0.983 + 0.00801 XX_IPCS +0.000001 XXXXTPSR

20 cases used 8 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	0.9835	0.7501	1.31	0.207
XX_IPCS	0.008005	0.004024	1.99	0.063
XXXXTPSR	0.00000063	0.00000711	0.09	0.930

s = 0.7450   R-sq = 62.6%   R-sq(adj) = 58.1%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	15.7634	7.8817	14.20	0.000
Error	17	9.4366	0.5551		
Total	19	25.2000			

SOURCE	DF	SEQ SS
XX_IPCS	1	15.7590
XXXXTPSR	1	0.0044

Unusual Observations

Obs.	XX_IPCS	Value	Fit	Stdev.Fit	Residual	St.Resid
17	323	5.000	3.598	0.415	1.402	2.27R

R denotes an obs. with a large st. resid.

C. Regression Analysis

The regression equation is
Value = 0.451 + 0.00648 XX_IPCS + 0.067 IncrProd

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	0.4508	0.9881	0.46	0.653
XX_IPCS	0.006475	0.003298	1.96	0.063
IncrProd	0.0670	0.1010	0.66	0.515

s = 0.7261   R-sq = 60.2%   R-sq(adj) = 56.4%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	16.7622	8.3811	15.90	0.000
Error	21	11.0711	0.5272		
Total	23	27.8333			

SOURCE	DF	SEQ SS
XX_IPCS	1	16.5305
IncrProd	1	0.2317

Unusual Observations

Obs.	XX_IPCS	Value	Fit	Stdev.Fit	Residual	St.Resid
21	168	1.000	2.476	0.321	-1.476	-2.27R
24	270	2.000	3.404	0.274	-1.404	-2.09R

R denotes an obs. with a large st. resid.

D. Regression Analysis

The regression equation is
Value = 0.993 + 0.00777 XX_IPCS + 0.00060 XX_IPROI

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	0.9929	0.5481	1.81	0.087
XX_IPCS	0.007769	0.003402	2.28	0.035
XX_IPROI	0.000601	0.003818	0.16	0.877

s = 0.7337 R-sq = 61.6% R-sq(adj) = 57.3%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	15.5476	7.7738	14.44	0.000
Error	18	9.6905	0.5384		
Total	20	25.2381			

SOURCE	DF	SEQ SS
XX_IPCS	1	15.5342
XX_IPROI	1	0.0134

Unusual Observations

Obs.	XX_IPCS	Value	Fit	Stdev.Fit	Residual	St.Resid
17	323	5.000	3.617	0.308	1.383	2.08R
21	168	1.000	2.366	0.323	-1.366	-2.07R

R denotes an obs. with a large st. resid.

E. Regression Analysis

The regression equation is
Value = 0.968 + 0.00711 XX_IPCS + 0.00146 XX_CSROI

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	0.9684	0.5479	1.77	0.094
XX_IPCS	0.007108	0.002887	2.46	0.024
XX_CSROI	0.001458	0.003133	0.47	0.647

s = 0.7299 R-sq = 62.0% R-sq(adj) = 57.8%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	15.6495	7.8248	14.69	0.000
Error	18	9.5886	0.5327		
Total	20	25.2381			

SOURCE	DF	SEQ SS
XX_IPCS	1	15.5342
XX_CSROI	1	0.1153

Unusual Observations

Obs.	XX_IPCS	Value	Fit	Stdev.Fit	Residual	St.Resid
17	323	5.000	3.512	0.353	1.488	2.33R
21	168	1.000	2.302	0.351	-1.302	-2.03R

R denotes an obs. with a large st. resid.

F. Regression Analysis

The regression equation is
Value = 0.951 + 0.00853 XX_IPCS - 0.00003 XX_TSCS

23 cases used 5 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	0.9505	0.5675	1.67	0.110
XX_IPCS	0.008534	0.003568	2.39	0.027
XX_TSCS	-0.000029	0.003325	-0.01	0.993

s = 0.7449 R-sq = 60.1% R-sq(adj) = 56.1%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	16.7284	8.3642	15.07	0.000
Error	20	11.0976	0.5549		
Total	22	27.8261			

SOURCE	DF	SEQ SS
XX_IPCS	1	16.7284
XX_TSCS	1	0.0000

Unusual Observations

Obs.	XX_IPCS	Value	Fit	Stdev.Fit	Residual	St.Resid
17	323	5.000	3.700	0.366	1.300	2.00R
21	168	1.000	2.380	0.368	-1.380	-2.13R

R denotes an obs. with a large st. resid.

G. Regression Analysis

The regression equation is
Value = 0.896 + 0.00731 XX_IPCS + 0.00134 XX_TSROI

20 cases used 8 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	0.8965	0.5622	1.59	0.129
XX_IPCS	0.007312	0.002377	3.08	0.007
XX_TSROI	0.001344	0.002372	0.57	0.578

s = 0.7383 R-sq = 63.2% R-sq(adj) = 58.9%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	15.9342	7.9671	14.62	0.000
Error	17	9.2658	0.5450		
Total	19	25.2000			

SOURCE	DF	SEQ SS
XX_IPCS	1	15.7590
XX_TSROI	1	0.1751

Unusual Observations

Obs.	XX_IPCS	Value	Fit	Stdev.Fit	Residual	St.Resid
17	323	5.000	3.447	0.367	1.553	2.42R

R denotes an obs. with a large st. resid.

H. Regression Analysis

The regression equation is
Value = 0.648 + 0.00756 XX_IPCS + 0.0336 TimeSav

23 cases used 5 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	0.6478	0.8194	0.79	0.438
XX_IPCS	0.007557	0.002433	3.11	0.006
TimeSav	0.03358	0.06673	0.50	0.620

s = 0.7402   R-sq = 60.6%   R-sq(adj) = 56.7%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	16.8672	8.4336	15.39	0.000
Error	20	10.9589	0.5479		
Total	22	27.8261			

SOURCE	DF	SEQ SS
XX_IPCS	1	16.7284
TimeSav	1	0.1388

Unusual Observations

Obs.	XX_IPCS	Value	Fit	Stdev.Fit	Residual	St.Resid
17	323	5.000	3.559	0.317	1.441	2.15R
21	168	1.000	2.287	0.366	-1.287	-2.00R

R denotes an obs. with a large st. resid.

I. Regression Analysis

The regression equation is
Value = 0.630 + 0.00727 XX_IPCS + 0.0467 IncrROI

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	0.6299	0.7237	0.87	0.396
XX_IPCS	0.007274	0.001986	3.66	0.002
IncrROI	0.04672	0.06182	0.76	0.460

s = 0.7229   R-sq = 62.7%   R-sq(adj) = 58.6%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	15.8327	7.9163	15.15	0.000
Error	18	9.4054	0.5225		
Total	20	25.2381			

SOURCE	DF	SEQ SS
XX_IPCS	1	15.5342
IncrROI	1	0.2984

Unusual Observations

Obs.	XX_IPCS	Value	Fit	Stdev.Fit	Residual	St.Resid
17	323	5.000	3.447	0.322	1.553	2.40R

R denotes an obs. with a large st. resid.

J. Regression Analysis

The regression equation is
Value = 1.52 + 0.0100 XX_IPCS - 0.057 CustSvc

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	1.519	1.073	1.42	0.171
XX_IPCS	0.010004	0.003192	3.13	0.005
CustSvc	-0.0573	0.1018	-0.56	0.579

s = 0.7282   R-sq = 60.0%   R-sq(adj) = 56.2%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	16.6985	8.3493	15.75	0.000
Error	21	11.1348	0.5302		
Total	23	27.8333			

SOURCE	DF	SEQ SS
XX_IPCS	1	16.5305
CustSvc	1	0.1680

Unusual Observations

Obs.	XX_IPCS	Value	Fit	Stdev.Fit	Residual	St.Resid
21	168	1.000	2.512	0.354	-1.512	-2.38R

R denotes an obs. with a large st. resid.

Summary Phase 3

Satisfaction 1-Variable	Adjusted R^2	p-value
XX_TSI Interaction	52.2	.505
XXXXTPSR Interaction	51.3	.930
IncrProd	50.8	.515
XX_IPROI Interaction	47.9	.877
XX_CSROI Interaction	46.5	.647
XX_TSCS Interaction	46.3	.993
XX_TSROI Interaction	39.6	.578
TimeSav	38.8	.620
IncrROI	31.5	.460
CustSvc	26.9	.579

Reject all variables

The regression equation is

Value* = 0.999 + 0.00842 *Improved Productivity / Customer Service

Appendix F: MODEL 3 - STATISTICAL ANALYSIS AND MODEL BUILDING

Statistical Analysis and Model Building - Length of Use

Step 1 Identify Independent Variables & Interaction Terms

Correlations (Pearson)

	LengUse	TimeSav	IncrProd	CustSvc	IncrROI	XX_TSIP	XX_TSCS	XX_TSROI
TimeSav	0.358							
IncrProd	0.404	0.737						
CustSvc	0.132	0.675	0.582					
IncrROI	0.079	0.808	0.507	0.649				
XX_TSIP	0.411	0.927	0.926	0.666	0.755			
XX_TSCS	0.282	0.932	0.737	0.885	0.795	0.891		
XX_TSROI	0.247	0.955	0.697	0.702	0.938	0.898	0.919	
XX_IPCS	0.305	0.776	0.890	0.876	0.646	0.895	0.902	0.760
XX_IPROI	0.192	0.874	0.843	0.763	0.882	0.953	0.898	0.930
XX_CSROI	0.225	0.847	0.655	0.879	0.927	0.843	0.931	0.923
XXXXTPSR	0.310	0.898	0.851	0.810	0.837	0.960	0.950	0.929

	XX_IPCS	XX_IPROI	XX_CSROI
XX_IPROI	0.893		
XX_CSROI	0.846	0.925	
XXXXTPSR	0.921	0.972	0.932

Step 2 - Identify Principle Independent Variable

A. Regression Analysis

The regression equation is
LengUse = 0.280 + 0.00482 XX_TSIP

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	0.2805	0.8332	0.34	0.740
XX_TSIP	0.004825	0.002282	2.11	0.046

s = 1.244 R-sq = 16.9% R-sq(adj) = 13.1%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	6.918	6.918	4.47	0.046
Error	22	34.041	1.547		
Total	23	40.958			

Unusual Observations

Obs.	XX_TSIP	LengUse	Fit	Stdev.Fit	Residual	St.Resid
1	462	5.000	2.510	0.364	2.490	2.09R
2	420	5.000	2.307	0.303	2.693	2.23R
8	440	5.000	2.403	0.330	2.597	2.16R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

B. Regression Analysis

The regression equation is
LengUse = - 0.99 + 0.162 IncrProd

25 cases used 3 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	-0.990	1.414	-0.70	0.491
IncrProd	0.16246	0.07669	2.12	0.045

s = 1.221   R-sq = 16.3%   R-sq(adj) = 12.7%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	6.687	6.687	4.49	0.045
Error	23	34.273	1.490		
Total	24	40.960			

Unusual Observations

Obs.	IncrProd	LengUse	Fit	Stdev.Fit	Residual	St.Resid
1	22.0	5.000	2.584	0.383	2.416	2.08R
2	21.0	5.000	2.421	0.327	2.579	2.19R
8	20.0	5.000	2.259	0.282	2.741	2.31R
28	10.0	1.000	0.634	0.672	0.366	0.36 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

No evidence of lack of fit (P > 0.1)

C. Regression Analysis

The regression equation is
LengUse = - 0.46 + 0.129 TimeSav

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	-0.460	1.368	-0.34	0.740
TimeSav	0.12925	0.07178	1.80	0.085

s = 1.274   R-sq = 12.8%   R-sq(adj) = 8.9%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	5.262	5.262	3.24	0.085
Error	22	35.697	1.623		
Total	23	40.958			

Unusual Observations

Obs.	TimeSav	LengUse	Fit	Stdev.Fit	Residual	St.Resid
1	21.0	5.000	2.255	0.308	2.745	2.22R
2	20.0	5.000	2.125	0.276	2.875	2.31R
8	22.0	5.000	2.384	0.351	2.616	2.14R

R denotes an obs. with a large st. resid.

No evidence of lack of fit (P > 0.1)

D. Regression Analysis

The regression equation is
LengUse = 1.16 +0.000005 XXXXTPSR

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	1.1625	0.4433	2.62	0.017
XXXXTPSR	0.00000514	0.00000361	1.42	0.171

s = 0.9823   R-sq = 9.6%   R-sq(adj) = 4.9%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	1.9508	1.9508	2.02	0.171
Error	19	18.3349	0.9650		
Total	20	20.2857			

Unusual Observations

Obs.	XXXXTPSR	LengUse	Fit	Stdev.Fit	Residual	St.Resid
8	157080	5.000	1.970	0.280	3.030	3.22R

R denotes an obs. with a large st. resid.

No evidence of lack of fit (P > 0.1)

E. Regression Analysis

The regression equation is
LengUse = 0.571 + 0.00403 XX_IPCS

25 cases used 3 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	0.5713	0.9394	0.61	0.549
XX_IPCS	0.004027	0.002622	1.54	0.138

s = 1.271   R-sq = 9.3%   R-sq(adj) = 5.4%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	3.809	3.809	2.36	0.138
Error	23	37.151	1.615		
Total	24	40.960			

Unusual Observations

Obs.	XX_IPCS	LengUse	Fit	Stdev.Fit	Residual	St.Resid
1	374	5.000	2.077	0.265	2.923	2.35R
2	378	5.000	2.094	0.269	2.906	2.34R
8	420	5.000	2.263	0.322	2.737	2.23R
28	120	1.000	1.055	0.642	-0.055	-0.05 X

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.

No evidence of lack of fit (P > 0.1)

F. Regression Analysis

The regression equation is
LengUse = 0.711 + 0.00347 XX_TSCS

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	0.7111	0.9441	0.75	0.459
XX_TSCS	0.003474	0.002522	1.38	0.182

s = 1.309 R-sq = 7.9% R-sq(adj) = 3.8%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	3.252	3.252	1.90	0.182
Error	22	37.707	1.714		
Total	23	40.958			

Unusual Observations

Obs.	XX_TSCS	LengUse	Fit	Stdev.Fit	Residual	St.Resid
1	357	5.000	1.951	0.267	3.049	2.38R
2	360	5.000	1.962	0.267	3.038	2.37R
8	462	5.000	2.316	0.373	2.684	2.14R

R denotes an obs. with a large st. resid.

No evidence of lack of fit (P > 0.1)

Summary Step 2

Satisfaction 1-Variable	Adjusted r^2	p-value
XX_TSIP Interaction	13.1	.046
IncrProd	12.7	.045
TimeSav	8.9	.085
XX_IPCS Interaction	5.4	.138
XXXXTPSR Interaction	4.9	.171
XX TSCS Interaction	3.8	.182

Select Time Savings / Increased Productivity interaction term as primary variable

Step 3 - Identify Secondary Variables

A. Regression Analysis

The regression equation is
LengUse = - 0.31 + 0.00301 XX_TSIP + 0.067 IncrProd

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	-0.305	2.035	-0.15	0.882	
XX_TSIP	0.003014	0.006170	0.49	0.630	7.0
IncrProd	0.0671	0.2116	0.32	0.754	7.0

s = 1.270   R-sq = 17.3%   R-sq(adj) = 9.4%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	7.080	3.540	2.19	0.136
Error	21	33.879	1.613		
Total	23	40.958			

SOURCE	DF	SEQ SS
XX_TSIP	1	6.918
IncrProd	1	0.162

Unusual Observations

Obs.	XX_TSIP	LengUse	Fit	Stdev.Fit	Residual	St.Resid
1	462	5.000	2.563	0.408	2.437	2.03R
2	420	5.000	2.369	0.366	2.631	2.16R
8	440	5.000	2.362	0.361	2.638	2.17R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

B. Regression Analysis

The regression equation is
LengUse = 0.75 + 0.00655 XX_TSIP - 0.057 TimeSav

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	0.750	1.781	0.42	0.678	
XX_TSIP	0.006547	0.006198	1.06	0.303	7.1
TimeSav	-0.0571	0.1904	-0.30	0.767	7.1

s = 1.270   R-sq = 17.2%   R-sq(adj) = 9.4%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	7.063	3.531	2.19	0.137
Error	21	33.895	1.614		
Total	23	40.958			

SOURCE	DF	SEQ SS
XX_TSIP	1	6.918
TimeSav	1	0.145

Unusual Observations

Obs.	XX_TSIP	LengUse	Fit	Stdev.Fit	Residual	St.Resid
1	462	5.000	2.576	0.432	2.424	2.03R
2	420	5.000	2.358	0.352	2.642	2.16R
8	440	5.000	2.374	0.351	2.626	2.15R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

C. Regression Analysis

The regression equation is
LengUse = 0.45 + 0.00508 XX_TSIP -0.000004 XXXXTPSR

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	0.453	1.040	0.44	0.668	
XX_TSIP	0.005085	0.006729	0.76	0.460	12.7
XXXXTPSR	-0.00000432	0.00001303	-0.33	0.744	12.7

s = 0.9936   R-sq = 12.4%   R-sq(adj) = 2.7%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	2.5146	1.2573	1.27	0.304
Error	18	17.7711	0.9873		
Total	20	20.2857			

SOURCE	DF	SEQ SS
XX_TSIP	1	2.4063
XXXXTPSR	1	0.1083

Unusual Observations

Obs.	XX_TSIP	LengUse	Fit	Stdev.Fit	Residual	St.Resid
8	440	5.000	2.013	0.289	2.987	3.14R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

D. Regression Analysis

The regression equation is
LengUse = 0.570 + 0.00807 XX_TSIP - 0.00409 XX_IPCS

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	0.5702	0.9392	0.61	0.550	
XX_TSIP	0.008070	0.005182	1.56	0.134	5.0
XX_IPCS	-0.004093	0.005851	-0.70	0.492	5.0

s = 1.259   R-sq = 18.8%   R-sq(adj) = 11.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	7.693	3.846	2.43	0.113
Error	21	33.266	1.584		
Total	23	40.958			

SOURCE	DF	SEQ SS
XX_TSIP	1	6.918
XX_IPCS	1	0.775

Unusual Observations

Obs.	XX_TSIP	LengUse	Fit	Stdev.Fit	Residual	St.Resid
2	420	5.000	2.413	0.342	2.587	2.14R
8	440	5.000	2.402	0.334	2.598	2.14R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

E. Regression Analysis

The regression equation is
LengUse = 0.604 + 0.00912 XX_TSIP - 0.00506 XX_TSCS

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	0.6041	0.9007	0.67	0.510	
XX_TSIP	0.009122	0.005041	1.81	0.085	4.9
XX_TSCS	-0.005063	0.005294	-0.96	0.350	4.9

s = 1.246   R-sq = 20.4%   R-sq(adj) = 12.8%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	8.339	4.169	2.68	0.092
Error	21	32.619	1.553		
Total	23	40.958			

SOURCE	DF	SEQ SS
XX_TSIP	1	6.918
XX_TSCS	1	1.421

Unusual Observations

Obs.	XX_TSIP	LengUse	Fit	Stdev.Fit	Residual	St.Resid
2	420	5.000	2.612	0.440	2.388	2.05R
8	440	5.000	2.278	0.355	2.722	2.28R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

F. Regression Analysis

The regression equation is
LengUse = 1.42 + 0.00649 XX_TSIP - 0.092 CustSvc

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	1.422	1.638	0.87	0.395	
XX_TSIP	0.006492	0.003083	2.11	0.047	1.8
CustSvc	-0.0916	0.1128	-0.81	0.426	1.8

s = 1.254   R-sq = 19.4%   R-sq(adj) = 11.7%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	7.954	3.977	2.53	0.104
Error	21	33.005	1.572		
Total	23	40.958			

SOURCE	DF	SEQ SS
XX_TSIP	1	6.918
CustSvc	1	1.036

Unusual Observations

Obs.	XX_TSIP	LengUse	Fit	Stdev.Fit	Residual	St.Resid
2	420	5.000	2.500	0.387	2.500	2.10R
8	440	5.000	2.355	0.338	2.645	2.19R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

G. Regression Analysis

```
The regression equation is
LengUse = 1.62 + 0.00527 XX_TSIP - 0.112 IncrROI

21 cases used 7 cases contain missing values

Predictor       Coef        Stdev     t-ratio        p       VIF
Constant       1.619        1.050        1.54    0.140
XX_TSIP     0.005267     0.002791        1.89    0.075       2.3
IncrROI      -0.1117       0.1013       -1.10    0.285       2.3

s = 0.9646      R-sq = 17.4%      R-sq(adj) = 8.3%

Analysis of Variance

SOURCE        DF          SS          MS          F        p
Regression     2      3.5371      1.7685       1.90    0.178
Error         18     16.7486      0.9305
Total         20     20.2857

SOURCE        DF      SEQ SS
XX_TSIP        1      2.4063
IncrROI        1      1.1308

Unusual Observations
Obs.  XX_TSIP    LengUse        Fit  Stdev.Fit    Residual    St.Resid
  8       440      5.000      2.038      0.281       2.962       3.21R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)
```

Summary Step 3

Satisfaction 2-Variable XX-TSIP Primary	**Adjusted R^2**	**p-value**
IncrProd	9.4	.754
TimeSav	9.4	.767
XX_IPCS Interaction	11.0	.492
XXXXTPSR Interaction	2.7	.744
XX_TSCS Interaction	12.8	.350

Reject all secondary variables

The regression equation is

Length off Use* = 0.280 + 0.00482 *Time Savings / Improved Productivity

Final Regression Analysis

The regression equation is
LengUse = 0.280 + 0.00482 XX_TSIP

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p
Constant	0.2805	0.8332	0.34	0.740
XX_TSIP	0.004825	0.002282	2.11	0.046

s = 1.244   R-sq = 16.9%   R-sq(adj) = 13.1%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	6.918	6.918	4.47	0.046
Error	22	34.041	1.547		
Total	23	40.958			

Unusual Observations

Obs.	XX_TSIP	LengUse	Fit	Stdev.Fit	Residual	St.Resid
1	462	5.000	2.510	0.364	2.490	2.09R
2	420	5.000	2.307	0.303	2.693	2.23R
8	440	5.000	2.403	0.330	2.597	2.16R

R denotes an obs. with a large st. resid.

No evidence of lack of fit (P > 0.1)

Appendix G: MODEL 4 - STATISTICAL ANALYSIS AND MODEL BUILDING

Statistical Analysis and Model Building - No. of Veh (Percentage of Fleet)

Step 1 Identify Independent Variables & Interaction Terms

Correlations (Pearson)

	No_Veh	TimeSav	IncrProd	CustSvc	IncrROI	XX_TSROI	XX_TSIP	XX_TSCS
TimeSav	0.379							
IncrProd	0.243	**0.737**						
CustSvc	0.362	**0.675**	**0.582**					
IncrROI	0.088	**0.808**	**0.507**	**0.649**				
XX_TSROI	0.257	0.955	0.697	0.702	0.938			
XX_TSIP	0.333	0.927	0.926	0.666	0.755	0.898		
XX_TSCS	0.421	0.932	0.737	0.885	0.795	0.919	0.891	
XX_CSROI	0.268	0.847	0.655	0.879	0.927	0.923	0.843	0.931
XX_IPCS	0.346	0.776	0.890	0.876	0.646	0.760	0.895	0.902
XX_IPROI	0.146	0.874	0.843	0.763	0.882	0.930	0.953	0.898
XXXXTPSR	0.308	0.898	0.851	0.810	0.837	0.929	0.960	0.950

	XX_CSROI	XX_IPCS	XX_IPROI
XX_IPCS	0.846		
XX_IPROI	0.925	0.893	
XXXXTPSR	0.932	0.921	0.972

Step 2 - Identify Principle Independent Variable

A. Regression Analysis

The regression equation is
No_Veh = 0.37 + 0.00686 XX_TSCS

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p		
Constant	0.372	1.178	0.32	0.755		
XX_TSCS	0.006856	0.003146	2.18	**0.040**	**p<0.10**	**Accept**

s = 1.633 R-sq = 17.8% R-sq(adj) = **14.0%**

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	12.662	12.662	4.75	**0.040**
Error	22	58.671	2.667		
Total	23	71.333			

No evidence of lack of fit (P > 0.1)

B. Regression Analysis

The regression equation is
No_Veh = 1.04 + 0.00516 XX_TSIP

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p		
Constant	1.038	1.137	0.91	0.371		
XX_TSIP	0.005162	0.003115	1.66	**0.112**	**p>0.10**	**Reject**

s = 1.698 R-sq = 11.1% R-sq(adj) = 7.1%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	7.919	7.919	2.75	0.112
Error	22	63.414	2.882		
Total	23	71.333			

No evidence of lack of fit (P > 0.1)

C. Regression Analysis

The regression equation is
No_Veh = 0.76 + 0.00603 XX_IPCS

25 cases used 3 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p		
Constant	0.762	1.222	0.62	0.539		
XX_IPCS	0.006026	0.003410	1.77	**0.090**	**p<0.10**	**Accept**

s = 1.653 R-sq = 12.0% R-sq(adj) = 8.1%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	8.529	8.529	3.12	0.090
Error	23	62.831	2.732		
Total	24	71.360			

Unusual Observations

Obs.	XX_IPCS	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
28	120	1.000	1.485	0.835	-0.485	-0.34 X

X denotes an obs. whose X value gives it large influence.

No evidence of lack of fit (P > 0.1)

D. Regression Analysis

The regression equation is
No_Veh = 1.62 +0.000008 XXXXTPSR

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p		
Constant	1.6203	0.7322	2.21	0.039		
XXXXTPSR	0.00000841	0.00000597	1.41	0.175	**p>0.10**	**Reject**

s = 1.622 R-sq = 9.5% R-sq(adj) = 4.7%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	5.230	5.230	1.99	0.175
Error	19	50.008	2.632		
Total	20	55.238			

Unusual Observations

Obs.	XXXXTPSR	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
11	28080	5.000	1.857	0.591	3.143	2.08R

R denotes an obs. with a large st. resid.

No evidence of lack of fit (P > 0.1)

E. Regression Analysis

The regression equation is
No_Veh = - 1.10 + 0.205 CustSvc

27 cases used 1 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p		
Constant	-1.099	2.000	-0.55	0.587		
CustSvc	0.2049	0.1054	1.94	**0.063**	**p<0.10**	**Accept**

s = 1.616 R-sq = 13.1% R-sq(adj) = 9.7%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	9.872	9.872	3.78	0.063
Error	25	65.313	2.613		
Total	26	75.185			

Unusual Observations

Obs.	CustSvc	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
21	12.0	1.000	1.360	0.776	-0.360	-0.25 X
28	12.0	1.000	1.360	0.776	-0.360	-0.25 X

X denotes an obs. whose X value gives it large influence.

Lack of fit test
Possible curvature in variable CustSvc (P = 0.039)
Overall lack of fit test is significant at P = 0.039

F. Regression Analysis

The regression equation is
No_Veh = 1.91 + 0.043 IncrROI

22 cases used 6 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p		
Constant	1.907	1.649	1.16	0.261		
IncrROI	0.0428	0.1080	0.40	0.696	**p>0.10**	**Reject**

s = 1.659 R-sq = 0.8% R-sq(adj) = 0.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	0.432	0.432	0.16	0.696
Error	20	55.023	2.751		
Total	21	55.455			

No evidence of lack of fit (P > 0.1)

G. Regression Analysis

The regression equation is
No_Veh = - 0.54 + 0.180 TimeSav

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p		
Constant	-0.543	1.789	-0.30	0.765		
TimeSav	0.18045	0.09389	1.92	**0.068**	**p<0.10**	**Accept**

s = 1.666 R-sq = 14.4% R-sq(adj) = 10.5%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	10.255	10.255	3.69	0.068
Error	22	61.078	2.776		
Total	23	71.333			

No evidence of lack of fit (P > 0.1)

H. Regression Analysis

The regression equation is
No_Veh = 0.50 + 0.129 IncrProd

25 cases used 3 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p		
Constant	0.500	1.979	0.25	0.803		
IncrProd	0.1288	0.1074	1.20	0.242	**p>0.10**	**Reject**

s = 1.709   R-sq = 5.9%   R-sq(adj) = 1.8%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	4.205	4.205	1.44	0.242
Error	23	67.155	2.920		
Total	24	71.360			

Unusual Observations

Obs.	IncrProd	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
28	10.0	1.000	1.789	0.940	-0.789	-0.55 X

X denotes an obs. whose X value gives it large influence.

No evidence of lack of fit (P > 0.1)

I. Regression Analysis

The regression equation is
No_Veh = 1.85 + 0.00255 XX_IPROI

22 cases used 6 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	
Constant	1.853	1.105	1.68	0.109	
XX_IPROI	0.002549	0.003857	0.66	0.516	**p>0.10 Reject**

s = 1.647   R-sq = 2.1%   R-sq(adj) = 0.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	1.185	1.185	0.44	0.516
Error	20	54.270	2.713		
Total	21	55.455			

No evidence of lack of fit (P > 0.1)

Summary Step 2

No. Veh 1-Variable	Adjusted r^2	p-value
XX_TSCS Interaction	**14.0**	**.040**
TimeSav	10.5	**.068**
CustSvc	9.7	**.063**
XX_IPCS Interaction	8.1	**.090**
XX_TSIP Interaction	7.1	.112
XXXXTPSR Interaction	4.7	.175
IncrProd	1.8	.242
IncrROI	0.0	.096
XX IPROI Interaction	0.0	.516

Select *Time Savings / Improved Customer Service* interaction variable.

Step 3 Identify Secondary Variables

A. Regression Analysis

```
The regression equation is
No_Veh = 0.72 + 0.00838 XX_TSCS - 0.048 TimeSav

24 cases used 4 cases contain missing values

Predictor        Coef        Stdev     t-ratio        p        VIF
Constant        0.720        2.235        0.32    0.750
XX_TSCS      0.008380     0.008848        0.95    0.354        7.6
TimeSav       -0.0479       0.2588       -0.18    0.855        7.6 p > 0.10 Reject

s = 1.670       R-sq = 17.9%      R-sq(adj) = 10.1%

Analysis of Variance

SOURCE        DF         SS          MS         F        p
Regression     2     12.758       6.379      2.29    0.126
Error         21     58.576       2.789
Total         23     71.333

SOURCE        DF     SEQ SS
XX_TSCS        1     12.662
TimeSav        1      0.095

No evidence of lack of fit (P > 0.1)
```

B. Regression Analysis

The regression equation is
No_Veh = 0.72 + 0.00445 XX_IPCS + 0.00164 XX_TSIP

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	0.723	1.287	0.56	0.580	
XX_IPCS	0.004447	0.008020	0.55	0.585	5.0
XX_TSIP	0.001636	0.007104	0.23	0.820	5.0 **p > 0.10 Reject**

s = 1.725 R-sq = 12.4% R-sq(adj) = 4.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	8.834	4.417	1.48	0.250
Error	21	62.500	2.976		
Total	23	71.333			

SOURCE	DF	SEQ SS
XX_IPCS	1	8.676
XX_TSIP	1	0.158

No evidence of lack of fit (P > 0.1)

C. Regression Analysis

The regression equation is
No_Veh = 0.91 + 0.00425 XX_IPCS +0.000002 XXXXTPSR

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	0.909	1.667	0.54	0.592	
XX_IPCS	0.004249	0.008898	0.48	0.639	6.6
XXXXTPSR	0.00000153	0.00001564	0.10	0.923	6.6 **p > 0.10 Reject**

s = 1.656 R-sq = 10.6% R-sq(adj) = 0.7%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	5.856	2.928	1.07	0.365
Error	18	49.382	2.743		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_IPCS	1	5.829
XXXXTPSR	1	0.026

No evidence of lack of fit (P > 0.1)

D. Regression Analysis

The regression equation is
No_Veh = - 0.68 + 0.00408 XX_TSCS + 0.109 CustSvc

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	-0.684	2.609	-0.26	0.796	
XX_TSCS	0.004083	0.006873	0.59	0.559	4.6
CustSvc	0.1092	0.2394	0.46	0.653	4.6 **p > 0.10 Reject**

s = 1.663   R-sq = 18.6%   R-sq(adj) = 10.8%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	13.237	6.619	2.39	0.116
Error	21	58.096	2.766		
Total	23	71.333			

SOURCE	DF	SEQ SS
XX_TSCS	1	12.662
CustSvc	1	0.575

Unusual Observations

Obs.	XX_TSCS	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
20	308	3.000	2.975	1.142	0.025	0.02 X

X denotes an obs. whose X value gives it large influence.
Lack of fit test
Possible curvature in variable CustSvc (P = 0.042)
Overall lack of fit test is significant at P = 0.042

E. Regression Analysis

The regression equation is
No_Veh = 2.62 + 0.0138 XX_TSCS - 0.332 IncrROI

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	2.620	1.538	1.70	0.106	
XX_TSCS	0.013835	0.004511	3.07	0.007	2.7
IncrROI	-0.3318	0.1602	-2.07	0.053	2.7 **p<0.10 Accept**

s = 1.410   R-sq = 35.2%   R-sq(adj) = 28.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	19.443	9.721	4.89	0.020
Error	18	35.795	1.989		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_TSCS	**1**	**10.917**
IncrROI	**1**	**8.526**

Unusual Observations

Obs.	XX_TSCS	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
28	132	1.000	-0.199	0.926	1.199	1.13 X

X denotes an obs. whose X value gives it large influence.
No evidence of lack of fit (P > 0.1)

F. Regression Analysis

The regression equation is
No_Veh = 0.50 + 0.00930 XX_TSCS - 0.00291 XX_IPCS

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	0.505	1.255	0.40	0.692	
XX_TSCS	0.009299	0.007424	1.25	0.224	5.3
XX_IPCS	-0.002914	0.007981	-0.37	0.719	5.3 **p > 0.10 Reject**

s = 1.666 R-sq = 18.3% R-sq(adj) = 10.5%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	13.032	6.516	2.35	0.120
Error	21	58.301	2.776		
Total	23	71.333			

SOURCE	DF	SEQ SS
XX_TSCS	1	12.662
XX_IPCS	1	0.370

No evidence of lack of fit (P > 0.1)

G. Regression Analysis

The regression equation is
No_Veh = 0.41 + 0.00984 XX_TSCS - 0.00319 XX_TSIP

24 cases used 4 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	0.410	1.202	0.34	0.737	
XX_TSCS	0.009837	0.007062	1.39	0.178	4.9
XX_TSIP	-0.003185	0.006724	-0.47	0.641	4.9 **p > 0.10 Reject**

s = 1.663 R-sq = 18.6% R-sq(adj) = 10.9%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	13.282	6.641	2.40	0.115
Error	21	58.051	2.764		
Total	23	71.333			

SOURCE	DF	SEQ SS
XX_TSCS	1	12.662
XX_TSIP	1	0.620

No evidence of lack of fit (P > 0.1)

H. Regression Analysis

The regression equation is
No_Veh = 0.53 + 0.0179 XX_TSCS - 0.0151 XX_CSROI

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	0.533	1.081	0.49	0.628	
XX_TSCS	0.017933	0.007803	2.30	0.034	7.5
XX_CSROI	-0.015141	0.009543	-1.59	0.130	7.5 **p > 0.10 Reject**

s = 1.470 R-sq = 29.6% R-sq(adj) = 21.8%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	16.355	8.178	3.79	0.042
Error	18	38.883	2.160		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_TSCS	1	10.917
XX_CSROI	1	5.438

No evidence of lack of fit (P > 0.1)

I. Regression Analysis

The regression equation is
No_Veh = 0.02 + 0.0193 XX_TSCS - 0.0151 XX_TSROI

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	0.020	1.034	0.02	0.985	
XX_TSCS	0.019293	0.006979	2.76	0.013	6.4
XX_TSROI	-0.015051	0.007492	-2.01	0.060	6.4 **p < 0.10 Accept**

s = 1.418 R-sq = 34.5% R-sq(adj) = 27.2%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	19.034	9.517	4.73	0.022
Error	18	36.204	2.011		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_TSCS	1	10.917
XX_TSROI	1	8.117

Unusual Observations

Obs.	XX_TSCS	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
13	360	5.000	2.149	0.368	2.851	2.08R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

J. Regression Analysis

The regression equation is
No_Veh = 0.582 + 0.0223 XX_TSCS - 0.0218 XX_IPROI

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	0.5821	0.9133	0.64	0.532	
XX_TSCS	0.022318	0.005523	4.04	0.001	5.2
XX_IPROI	-0.021805	0.006799	-3.21	0.005	5.2 **p < 0.10 Accept**

s = 1.252 R-sq = 48.9% R-sq(adj) = 43.3%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	27.033	13.516	8.63	0.002
Error	18	28.205	1.567		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_TSCS	1	10.917
XX_IPROI	1	16.116

Improperly built model
Seq. SS **NOT** in descending order.

Unusual Observations

Obs.	XX_TSCS	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
12	399	1.000	3.905	0.452	-2.905	-2.49R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

K. Regression Analysis

The regression equation is
No_Veh = 0.582 - 0.0218 XX_IPROI + 0.0223 XX_TSCS

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	0.5821	0.9133	0.64	0.532	
XX_IPROI	-0.021805	0.006799	-3.21	0.005	5.2
XX_TSCS	0.022318	0.005523	4.04	0.001	5.2 **p < 0.10 Accept**

s = 1.252 R-sq = 48.9% R-sq(adj) = 43.3%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	2	27.033	13.516	8.63	0.002
Error	18	28.205	1.567		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_IPROI	1	1.447
XX_TSCS	1	25.586

Improperly built model
Seq. SS **NOT** in descending order.

Unusual Observations

Obs.	XX_IPROI	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
12	256	1.000	3.905	0.452	-2.905	-2.49R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

Summary Step-3

No. Veh 2-Variable XX_TSCS +	Adjusted R^2	p-value
XX_IPROI Interaction	43.3*	**.005**
IncrROI	**28.0**	**.053**
XX_TSROI Interaction	27.2	**.060**
XX_CSROI Interaction	21.8	.130
XX_TSIP Interaction	10.9	.641
CustSvc	10.8	.653
XX_IPCS Interaction	10.5	.719
TimeSav	10.1	.855
IncrProd	1.8	.242
XXXXTPSR Interaction	0.7	.923

* XX_IPROI and XX_TSCS did not properly build sequential sum of squares. XX_IPROI was **NOT** significant as primary variable.

Table XXX

Select *IncrROI* as significant second variable. Variables selected on a 94% confidence level.

Step 4 - Identify Tertiary Variables

A. Regression Analysis

The regression equation is
No_Veh = 3.47 + 0.0239 XX_TSCS - 0.388 IncrROI - 0.0105 XX_IPCS

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	3.470	1.585	2.19	0.043	
XX_TSCS	0.023862	0.007883	3.03	0.008	8.9
IncrROI	-0.3880	0.1590	-2.44	0.026	2.9
XX_IPCS	-0.010461	0.006856	-1.53	0.145	5.8 **p>0.10 Reject**

s = 1.361   R-sq = 43.0%   R-sq(adj) = 32.9%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	3	23.754	7.918	4.28	0.020
Error	17	31.484	1.852		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_TSCS	1	10.917
IncrROI	1	8.526
XX_IPCS	1	4.311

Unusual Observations

Obs.	XX_TSCS	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
12	399	1.000	3.603	0.597	-2.603	-2.13R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

B. Regression Analysis

The regression equation is
No_Veh = 3.21 + 0.0167 XX_TSCS - 0.313 IncrROI - 0.102 TimeSav

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	3.207	2.203	1.46	0.164	
XX_TSCS	0.016704	0.008830	1.89	0.076	9.9
IncrROI	-0.3135	0.1711	-1.83	0.084	3.0
TimeSav	-0.1018	0.2671	-0.38	0.708	10.5 **p>0.10 Reject**

s = 1.445   R-sq = 35.7%   R-sq(adj) = 24.4%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	3	19.746	6.582	3.15	0.052
Error	17	35.492	2.088		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_TSCS	1	10.917
IncrROI	1	8.526
TimeSav	1	0.304

Unusual Observations

Obs.	XX_TSCS	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
13	360	5.000	2.168	0.470	2.832	2.07R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

C. Regression Analysis

The regression equation is
No_Veh = 1.82 + 0.0118 XX_TSCS - 0.317 IncrROI + 0.070 CustSvc

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	1.822	3.088	0.59	0.563	
XX_TSCS	0.011750	0.008343	1.41	0.177	8.8
IncrROI	-0.3172	0.1715	-1.85	0.082	3.0
CustSvc	0.0703	0.2341	0.30	0.768	5.4 **p>0.10 Reject**

s = 1.447 R-sq = 35.5% R-sq(adj) = 24.2%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	3	19.632	6.544	3.12	0.053
Error	17	35.606	2.094		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_TSCS	1	10.917
IncrROI	1	8.526
CustSvc	1	0.189

Unusual Observations

Obs.	XX_TSCS	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
20	308	3.000	2.230	1.149	0.770	0.88 X

X denotes an obs. whose X value gives it large influence.

No evidence of lack of fit (P > 0.1)

D. Regression Analysis

The regression equation is
No_Veh = 0.44 + 0.0226 XX_TSCS - 0.242 IncrROI -0.000022 XXXXTPSR

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	0.443	2.394	0.18	0.855	
XX_TSCS	0.022636	0.008705	2.60	0.019	10.3
IncrROI	-0.2422	0.1759	-1.38	0.186	3.3
XXXXTPSR	-0.00002156	0.00001831	-1.18	0.255	12.7 **p>0.10 Reject**

s = 1.395 R-sq = 40.1% R-sq(adj) = 29.5%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	3	22.143	7.381	3.79	0.030
Error	17	33.096	1.947		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_TSCS	1	10.917
IncrROI	1	8.526
XXXXTPSR	1	2.700

No evidence of lack of fit (P > 0.1)

E. Regression Analysis

The regression equation is
No_Veh = 1.07 + 0.0223 XX_TSCS - 0.073 IncrROI - 0.0196 XX_IPROI

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	1.073	1.567	0.68	0.503	
XX_TSCS	0.022347	0.005658	3.95	0.001	5.2
IncrROI	-0.0733	0.1877	-0.39	0.701	4.5
XX_IPROI	-0.019595	0.008974	-2.18	0.043	8.6 **p<0.10 Accept**

s = 1.282   R-sq = 49.4%   **R-sq(adj) = 40.5%**

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	3	27.284	9.095	5.53	0.008
Error	17	27.954	1.644		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_TSCS	1	10.917
IncrROI	1	8.526
XX_IPROI	1	7.841

Proper model build

Unusual Observations

Obs.	XX_TSCS	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
12	399	1.000	3.800	0.535	-2.800	-2.40R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

F. Regression Analysis

The regression equation is
No_Veh = 2.49 + 0.0256 XX_TSCS - 0.311 IncrROI - 0.0129 XX_TSIP

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	2.489	1.437	1.73	0.101	
XX_TSCS	0.025644	0.007481	3.43	0.003	8.6
IncrROI	-0.3115	0.1500	-2.08	0.053	2.7
XX_TSIP	-0.012926	0.006767	-1.91	0.073	7.3

s = 1.317   R-sq = 46.6%   R-sq(adj) = 37.2%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	3	25.768	8.589	4.95	0.012
Error	17	29.470	1.734		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_TSCS	1	10.917
IncrROI	1	8.526
XX_TSIP	1	6.325

Unusual Observations

Obs.	XX_TSCS	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
13	360	5.000	2.342	0.311	2.658	2.08R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

G. Regression Analysis

The regression equation is
No_Veh = 2.68 + 0.0135 XX_TSCS - 0.342 IncrROI + 0.0007 XX_CSROI

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	2.677	2.067	1.30	0.212	
XX_TSCS	0.013524	0.008519	1.59	0.131	9.2
IncrROI	-0.3418	0.2820	-1.21	0.242	8.0
XX_CSROI	0.00070	0.01611	0.04	0.966	21.9 **p > 0.10 Reject**

s = 1.451 R-sq = 35.2% R-sq(adj) = 23.8%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	3	19.447	6.482	3.08	0.056
Error	17	35.791	2.105		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_TSCS	1	10.917
IncrROI	1	8.526
XX_CSROI	1	0.004

No evidence of lack of fit (P > 0.1)

H. Regression Analysis

The regression equation is
No_Veh = 1.62 + 0.0168 XX_TSCS - 0.206 IncrROI - 0.0068 XX_TSROI

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	1.615	2.746	0.59	0.564	
XX_TSCS	0.016816	0.008119	2.07	0.054	8.4
IncrROI	-0.2056	0.3270	-0.63	0.538	10.8
XX_TSROI	-0.00678	0.01520	-0.45	0.661	25.6 **p > 0.10 Reject**

s = 1.443 R-sq = 35.9% R-sq(adj) = 24.6%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	3	19.857	6.619	3.18	0.051
Error	17	35.381	2.081		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_TSCS	1	10.917
IncrROI	1	8.526
XX_TSROI	1	0.414

Unusual Observations

Obs.	XX_TSCS	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
13	360	5.000	2.209	0.386	2.791	2.01R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

I. Regression Analysis

```
The regression equation is
No_Veh = 5.99 + 0.0221 XX_TSCS - 0.382 IncrROI - 0.312 IncrProd

21 cases used 7 cases contain missing values

Predictor        Coef       Stdev    t-ratio        p        VIF
Constant        5.989       2.024       2.96    0.009
XX_TSCS      0.022071    0.005433       4.06    0.001        4.9
IncrROI       -0.3816      0.1459      -2.62    0.018        2.8
IncrProd      -0.3116      0.1365      -2.28    0.036        2.6 p < .10 Accept

s = 1.270        R-sq = 50.4%      R-sq(adj) = 41.6%

Analysis of Variance

SOURCE        DF         SS          MS         F        p
Regression     3     27.837       9.279      5.76    0.007
Error         17     27.401       1.612
Total         20     55.238

SOURCE        DF     SEQ SS
XX_TSCS        1     10.917
IncrROI        1      8.526
IncrProd       1      8.394
```

Properly built model
Seq SS. in descending order.

```
Unusual Observations
Obs.  XX_TSCS     No_Veh       Fit   Stdev.Fit   Residual    St.Resid
 11       270      5.000     4.845       0.969      0.155      0.19 X
 12       399      1.000     3.704       0.484     -2.704     -2.30R
 13       360      5.000     2.532       0.317      2.468      2.01R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.
```

No evidence of lack of fit (P > 0.1)

Summary Step 4

No. Veh 3-Variable XX_TSCS & IncrROI +	**Adjusted R^2**	**p-value**
IncrProd	**41.6**	**.036**
XX_IPROI Interaction	40.5	**.043**
XX_TSIP Interaction	37.2	**.073**
XX_IPCS Interaction	32.9	.145
XXXXTPSR Interaction	29.5	.255
XX_TSROI Interaction	24.6	.661
TimeSav	24.4	.708
CustSvc	24.2	.768
XX_CSROI Interaction	23.8	.966

Select *IncrProd* for tertiary variable.

Step 5 - Identify Supplementary Variables

A. Regression Analysis

* NOTE * XX_IPROI is highly correlated with other predictor variables
The regression equation is
No_Veh = 5.43 + 0.0222 XX_TSCS - 0.345 IncrROI - 0.277 IncrProd 0.0024 XX_IPROI

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF	
Constant	5.428	7.758	0.70	0.494		
XX_TSCS	0.022179	0.005781	3.84	0.001	5.2	
IncrROI	-0.3449	0.5107	-0.68	0.509	32.1	
IncrProd	-0.2769	0.4828	-0.57	0.574	30.9	
XX_IPROI	-0.00236	0.03141	-0.08	0.941	101.1	**p > 0.10 Reject**

s = 1.308 R-sq = 50.4% R-sq(adj) = 38.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	4	27.847	6.962	4.07	0.018
Error	16	27.391	1.712		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_TSCS	1	10.917
IncrROI	1	8.526
IncrProd	1	8.394
XX_IPROI	1	0.010

Unusual Observations

Obs.	XX_TSCS	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
12	399	1.000	3.724	0.562	-2.724	-2.31R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

B. Regression Analysis

The regression equation is
No_Veh = 6.00 + 0.0221 XX_TSCS - 0.382 IncrROI - 0.312 IncrProd + 0.0000 XX_TSIP

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF	
Constant	5.995	3.495	1.72	0.106		
XX_TSCS	0.022058	0.008119	2.72	0.015	10.2	
IncrROI	-0.3817	0.1622	-2.35	0.032	3.2	
IncrProd	-0.3122	0.2840	-1.10	0.288	10.7	
XX_TSIP	0.00003	0.01357	0.00	0.998	29.8	**p > 0.10 Reject**

s = 1.309 R-sq = 50.4% R-sq(adj) = 38.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	4	27.837	6.959	4.06	0.018
Error	16	27.401	1.713		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_TSCS	1	10.917
IncrROI	1	8.526
IncrProd	1	8.394
XX_TSIP	1	0.000

Unusual Observations

Obs.	XX_TSCS	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
12	399	1.000	3.705	0.509	-2.705	-2.24R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

C. Regression Analysis

The regression equation is
No_Veh = 6.51 + 0.0197 XX_TSCS - 0.369 IncrROI - 0.396 IncrProd + 0.0048 XX_IPCS

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	6.511	2.425	2.69	0.016	
XX_TSCS	0.019697	0.007972	2.47	0.025	10.0
IncrROI	-0.3692	0.1525	-2.42	0.028	2.9
IncrProd	-0.3960	0.2464	-1.61	0.128	8.1
XX_IPCS	0.00480	0.01154	0.42	0.683	18.0 **p > 0.10 Reject**

s = 1.302 R-sq = 50.9% R-sq(adj) = 38.7%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	4	28.131	7.033	4.15	0.017
Error	16	27.107	1.694		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_TSCS	1	10.917
IncrROI	1	8.526
IncrProd	1	8.394
XX_IPCS	1	0.293

Unusual Observations

Obs.	XX_TSCS	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
12	399	1.000	3.587	0.572	-2.587	-2.21R
13	360	5.000	2.432	0.404	2.568	2.08R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

D. Regression Analysis

The regression equation is
No_Veh = 7.55 + 0.0196 XX_TSCS - 0.430 IncrROI - 0.366 IncrProd +0.000010 XXXXTPSR

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	7.549	4.397	1.72	0.105	
XX_TSCS	0.019605	0.008282	2.37	0.031	10.8
IncrROI	-0.4302	0.1923	-2.24	0.040	4.6
IncrProd	-0.3664	0.1952	-1.88	0.079	5.1
XXXXTPSR	0.00000959	0.00002382	0.40	0.693	24.7 **p > 0.10 Reject**

s = 1.302 R-sq = 50.9% R-sq(adj) = 38.6%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	4	28.112	7.028	4.15	0.017
Error	16	27.126	1.695		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_TSCS	1	10.917
IncrROI	1	8.526
IncrProd	1	8.394
XXXXTPSR	1	0.275

Unusual Observations

Obs.	XX_TSCS	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
12	399	1.000	3.606	0.554	-2.606	-2.21R
13	360	5.000	2.435	0.405	2.565	2.07R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

E. Regression Analysis

The regression equation is
No_Veh = 5.33 + 0.0238 XX_TSCS - 0.304 IncrROI - 0.308 IncrProd   0.0042 XX_TSROI

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	5.334	3.011	1.77	0.096	
XX_TSCS	0.023799	0.008009	2.97	0.009	10.0
IncrROI	-0.3037	0.2991	-1.02	0.325	11.1
IncrProd	-0.3079	0.1409	-2.19	0.044	2.6
XX_TSROI	-0.00415	0.01380	-0.30	0.767	25.8 **p > 0.10 Reject**

s = 1.305   R-sq = 50.7%   R-sq(adj) = 38.3%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	4	27.992	6.998	4.11	0.018
Error	16	27.247	1.703		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_TSCS	1	10.917
IncrROI	1	8.526
IncrProd	1	8.394
XX_TSROI	1	0.154

Unusual Observations

Obs.	XX_TSCS	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
12	399	1.000	3.649	0.531	-2.649	-2.22R
13	360	5.000	2.479	0.370	2.521	2.01R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

F. Regression Analysis

The regression equation is
No_Veh = 6.52 + 0.0247 XX_TSCS - 0.365 IncrROI - 0.311 IncrProd - 0.094 TimeSav

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	6.520	2.485	2.62	0.018	
XX_TSCS	0.024687	0.008735	2.83	0.012	12.0
IncrROI	-0.3646	0.1559	-2.34	0.033	3.0
IncrProd	-0.3108	0.1401	-2.22	0.041	2.6
TimeSav	-0.0936	0.2408	-0.39	0.702	10.5 **p > 0.10 Reject**

s = 1.303   R-sq = 50.9%   R-sq(adj) = 38.6%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	4	28.094	7.023	4.14	0.017
Error	16	27.144	1.697		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_TSCS	1	10.917
IncrROI	1	8.526
IncrProd	1	8.394
TimeSav	1	0.257

Unusual Observations

Obs.	XX_TSCS	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
12	399	1.000	3.597	0.568	-2.597	-2.22R
13	360	5.000	2.418	0.439	2.582	2.11R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

G. Regression Analysis

The regression equation is
No_Veh = 5.40 + 0.0205 XX_TSCS - 0.371 IncrROI - 0.310 IncrProd + 0.051 CustSvc

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	5.400	3.225	1.67	0.113	
XX_TSCS	0.020534	0.008518	2.41	0.028	11.3
IncrROI	-0.3709	0.1567	-2.37	0.031	3.0
IncrProd	-0.3102	0.1406	-2.21	0.042	2.6
CustSvc	0.0506	0.2115	0.24	0.814	5.4 **p > 0.10 Reject**

s = 1.306 R-sq = 50.6% R-sq(adj) = 38.2%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	4	27.935	6.984	4.09	0.018
Error	16	27.303	1.706		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_TSCS	1	10.917
IncrROI	1	8.526
IncrProd	1	8.394
CustSvc	1	0.098

Unusual Observations

Obs.	XX_TSCS	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
12	399	1.000	3.657	0.536	-2.657	-2.23R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

H. Regression Analysis

The regression equation is
No_Veh = 6.27 + 0.0208 XX_TSCS - 0.426 IncrROI - 0.314 IncrProd + 0.0031 XX_CSROI

21 cases used 7 cases contain missing values

Predictor	Coef	Stdev	t-ratio	p	VIF
Constant	6.267	2.462	2.55	0.022	
XX_TSCS	0.020762	0.008333	2.49	0.024	10.8
IncrROI	-0.4257	0.2568	-1.66	0.117	8.1
IncrProd	-0.3138	0.1409	-2.23	0.041	2.6
XX_CSROI	0.00308	0.01455	0.21	0.835	22.0 **p > 0.10 Reject**

s = 1.307 R-sq = 50.5% R-sq(adj) = 38.2%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	4	27.914	6.979	4.09	0.018
Error	16	27.324	1.708		
Total	20	55.238			

SOURCE	DF	SEQ SS
XX_TSCS	1	10.917
IncrROI	1	8.526
IncrProd	1	8.394
XX_CSROI	1	0.077

Unusual Observations

Obs.	XX_TSCS	No_Veh	Fit	Stdev.Fit	Residual	St.Resid
12	399	1.000	3.656	0.547	-2.656	-2.24R
13	360	5.000	2.484	0.398	2.516	2.02R

R denotes an obs. with a large st. resid.
No evidence of lack of fit (P > 0.1)

Summary Step 5

No. Veh 4-Variable XX_TSCS & IncrROI & IncrProd +	Adjusted R^2	p-value
XX_IPCS Interaction	38.7	.683
XXXXTPSR Interaction	38.6	.693
TimeSav	38.6	.702
XX_TSROI Interaction	38.3	.767
CustSvc	38.2	.814
XX_CSROI Interaction	38.2	.835
XX_IPROI Interaction	38.0	.941
XX_TSIP Interaction	38.0	.998

No additional variables enter the model. Final model for *No. of Veh.* is:

No. of Vehicles* = 5.99 + 0.0221 *Time Savings / Customer Service* - 0.382 *Increased ROI* - 0.312 *Increased Productivity

Final Regression Analysis

```
The regression equation is
No_Veh = 5.99 + 0.0221 XX_TSCS - 0.382 IncrROI - 0.312 IncrProd

21 cases used 7 cases contain missing values

Predictor        Coef       Stdev    t-ratio        p       VIF
Constant        5.989       2.024       2.96    0.009
XX_TSCS      0.022071    0.005433       4.06    0.001       4.9
IncrROI       -0.3816      0.1459      -2.62    0.018       2.8
IncrProd      -0.3116      0.1365      -2.28    0.036       2.6

s = 1.270       R-sq = 50.4%      R-sq(adj) = 41.6%

Analysis of Variance

SOURCE       DF        SS         MS         F        p
Regression    3    27.837      9.279      5.76    0.007
Error        17    27.401      1.612
Total        20    55.238

SOURCE       DF    SEQ SS
XX_TSCS       1    10.917
IncrROI       1     8.526                Proper Model Build
IncrProd      1     8.394

Unusual Observations
Obs.  XX_TSCS     No_Veh        Fit  Stdev.Fit   Residual    St.Resid
 11       270      5.000      4.845      0.969      0.155      0.19 X
 12       399      1.000      3.704      0.484     -2.704     -2.30R
 13       360      5.000      2.532      0.317      2.468      2.01R

R denotes an obs. with a large st. resid.
X denotes an obs. whose X value gives it large influence.
No evidence of lack of fit (P > 0.1)
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